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Estimates of Urban Roadway Congestion - 1990

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Estimates of Urban Roadway Congestion - 1990

Interim Report
March 1993

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16. Abstract

This research report is the fifth year continuation of a six year research effort focused on quantifying urban mobility. This study contain the facility information for 50 urban areas throughout the country. The database used for this research contains vehicle-miles of travel, urban area information, and facility mileage data from 1982 to 1990. Various federal, state, and local agencies provided the information used to update and verify the primary database. The primary database and source of information is the Federal Highway Administration's Highway Performance Monitoring System (HPMS).

Vehicle-miles of travel and lane-mile data were combined to develop Roadway Congestion Index (RCI) values for 50 urban areas including the seven largest in Texas. These RCI values provide an indicator of the relative mobility level within an urban area.

An analysis of the impacts and cost of congestion were also performed using travel delay, increased fuel consumption, and additional facility lane-miles as measures of urban mobility. Congestion costs were estimated on an areawide, per registered vehicle, and per capita basis.

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ABSTRACT

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Vehicle-miles of travel and lane-mile data were combined to develop Roadway Congestion Index (RCI) values for 50 urban areas including the seven largest in Texas. These RCI values provide an indicator of the relative mobility level within an urban area.

An analysis of the impacts and cost of congestion was also performed using travel delay, increased fuel consumption, and additional facility lane-miles as measures of urban mobility. Congestion costs were estimated on an areawide, per registered vehicle, and per capita basis.

Key Words: Mobility, Congestion, Economic Analysis, Transportation Planning, Travel Delay.

IMPLEMENTATION STATEMENT

To determine future highway needs and assist the Texas Department of Transportation in planning, it is desirable to measure and monitor the severity of congestion in the large Texas metropolitan areas. This report provides a quantification of those congestion levels and the economic impact of congestion on urban motorists. The report also presents data on other large metropolitan areas throughout the country to assist in determining nationwide mobility trends. Information in this report should be of value in identifying transportation trends and prioritizing needs for the future.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. In addition, this report is not intended for construction, bidding, or permit purposes. David L. Schrank, Shawn M. Turner and Timothy J. Lomax (Texas Professional Engineer certification number 54597) prepared this research report.

SUMMARY

This report represents the fifth year of a planned six-year study to measure and monitor urban mobility in 50 urbanized areas throughout the United States. This research study estimates the level of congestion in the seven largest Texas urban areas and 43 other areas representing a cross-section of urban areas throughout the country. Quantitative estimates of mobility levels allow comparisons of transportation systems in the various urbanized areas and assist the transportation community in analyzing urban mobility.

The level of congestion in an urban area was estimated using procedures developed in previous research (1,2,3,4,5,6). The Roadway Congestion Index (RCI) combines the daily vehicle-miles of travel per lane-mile (DVMT) for freeways and principal arterial street systems in a ratio comparing the existing DVMT to calculated DVMT values identified with congested conditions. Equation S-1 illustrates how the areawide and congested level DVMTs are combined into the RCI values for each urban area.

$$\text{Roadway Congestion Index} = \frac{\left[\text{Freeway VMT/Ln.-Mi.} \times \text{Freeway VMT} + \text{Prin Art Str VMT/Ln.-Mi.} \times \text{Prin Art Str VMT}\right]}{\left[13{,}000 \times \text{Freeway VMT} + 5{,}000 \times \text{Prin Art Str VMT}\right]} \qquad \text{Eq. S-1}$$

An RCI value of 1.0 or greater indicates that congested conditions exist areawide. It should be noted that urban areas with areawide values less than 1.0 may have sections of roadway that experience periods of heavy congestion, but the average mobility level within the urban area could be defined as uncongested. The RCI analyses presented in this report are intended to evaluate entire urban areas and not specific locations. The nature of the RCI equation (Eq. S-1) is to underestimate point or specific facility congestion if the overall system has "good" operational characteristics.

Areawide Mobility

Table S-1 combines the freeway and principal arterial street system DVMT and DVMT per lane-mile into the 1990 estimated roadway congestion index (RCI). The eleven most congested urban areas in the study are displayed. The RCI values range from 1.55 (Los Angeles) to 1.12 (Houston and New Orleans). All of these urban areas have surpassed the point (1.0) at which undesirable levels of congestion occur.

Table S-1. 1990 Roadway Congestion Levels

Urban Area	Freeway / Expressway		Principal Arterial Street		Roadway[3] Congestion Index	Rank
	DVMT[1] (1000)	DVMT/[2] Ln-Mile	DVMT[1] (1000)	DVMT/[2] Ln-Mile		
Los Angeles CA	110,350	21,100	80,370	6,480	1.55	1
Washington DC	25,340	16,610	19,560	8,500	1.37	2
San Fran-Oak CA	42,590	17,820	14,000	6,110	1.35	3
Miami FL	8,570	14,170	15,810	7,620	1.26	4
Chicago IL	38,030	15,680	29,050	6,980	1.25	5
San Diego CA	27,690	16,050	9,340	5,460	1.22	6
Seattle-Everett WA	18,920	15,640	9,130	5,800	1.20	7
San Bernardino-Riv CA	14,580	16,290	10,150	4,740	1.19	8
New York NY	82,920	14,050	52,060	6,890	1.14	9
Houston TX	28,230	14,700	10,830	5,080	1.12	10
New Orleans LA	4,970	13,810	4,100	6,560	1.12	10

Notes: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile
[3] See Equation S-1

See Table 1 for complete listing of urban areas.
Source: TTI Analysis

The ten urban areas which have experienced the greatest growth in congestion between 1982 and 1990 are displayed in Table S-2. The RCI values reflect the level of congestion occurring in the urban areas. San Diego experienced a 56 percent increase in congestion during the nine year period. The congestion increase rate in all cities in the top ten exceeded two percent per year.

Table S-2. Fastest Congestion Growth Areas

Urban Area	Year 1982	1983	1984	1985	1986	1987	1988	1989	1990	Percent Change 1982 to 1990
Atlanta GA	0.89	0.94	0.97	1.02	1.09	1.11	1.14	1.14	1.11	25
Dallas TX	0.84	0.89	0.94	0.98	1.04	1.02	1.02	1.02	1.05	25
Minn-St. Paul MN	0.74	0.79	0.81	0.83	0.87	0.87	0.88	0.90	0.93	26
Seattle-Everett WA	0.95	0.99	1.02	1.05	1.09	1.14	1.17	1.21	1.20	26
Los Angeles CA	1.22	1.27	1.32	1.36	1.42	1.47	1.52	1.54	1.55	27
Sacramento CA	0.80	0.84	0.88	0.92	0.95	1.00	1.03	1.01	1.02	27
Washington DC	1.07	1.09	1.12	1.20	1.28	1.30	1.32	1.36	1.37	28
San Fran-Oak CA	1.01	1.05	1.12	1.17	1.24	1.31	1.33	1.36	1.35	34
Salt Lake City UT	0.63	0.63	0.65	0.68	0.68	0.70	0.72	0.81	0.85	35
San Diego CA	0.78	0.83	0.91	0.95	1.00	1.08	1.13	1.18	1.22	56

See Table 6 for complete listing of urban areas.

Source: TTI Analysis

The twelve urban areas with the smallest growth in congestion between 1982 and 1990 are shown in Table S-3. Phoenix, Houston, and Detroit all experienced decreases in congestion with Phoenix showing the greatest decrease (10 percent). Congestion increases in these areas were less than one percent per year.

Table S-3. Slowest Congestion Growth Areas

Urban Area	Year 1982	1983	1984	1985	1986	1987	1988	1989	1990	Percent Change 1982 to 1990
Phoenix AZ	1.15	1.16	1.10	1.13	1.20	1.18	1.00	1.03	1.03	-10
Houston TX	1.17	1.21	1.25	1.23	1.21	1.19	1.15	1.13	1.12	-4
Detroit MI	1.13	1.10	1.13	1.12	1.11	1.10	1.09	1.08	1.09	-4
Louisville KY	0.84	0.82	0.81	0.79	0.80	0.88	0.87	0.86	0.86	2
Philadelphia PA	1.00	1.03	1.04	0.90	1.06	1.06	1.07	1.05	1.05	5
Pittsburgh PA	0.78	0.76	0.76	0.78	0.79	0.79	0.81	0.82	0.82	5
Memphis TN	0.86	0.80	0.76	0.75	0.77	0.84	0.86	0.91	0.91	6
Corpus Christi TX	0.67	0.69	0.69	0.71	0.71	0.72	0.70	0.71	0.72	7
Jacksonville FL	0.87	0.98	0.98	0.98	0.95	0.94	0.95	0.93	0.94	8
Orlando FL	0.66	0.68	0.67	0.71	0.71	0.72	0.74	0.72	0.72	9
San Bernardino-Riv CA	1.09	1.11	1.12	1.11	1.14	1.13	1.16	1.16	1.19	9
Ft. Lauderdale FL	0.86	0.85	0.84	0.84	0.84	0.90	0.90	0.92	0.94	9

See Table 6 for complete listing of urban areas
Source: TTI Analysis

Table S-4 combines existing lane-miles on both freeway and principal arterial streets with recent annual growth rates (1987 to 1990) of the daily vehicle-miles travelled (DVMT) on these facilities to produce the number of additional lane-miles which would be necessary to avoid increases in areawide congestion. This value illustrates the amount of roadway that would have to be added *every year* to maintain a constant congestion level. Los Angeles would require 665 lane-miles (197 freeway, 468 principal arterial street) to maintain current levels of mobility.

The urban area with the smallest additional lane-miles in this summary group, San Francisco-Oakland, would require 126 lane-miles (64 freeway, 62 principal arterial street). Roadway mileage has not been constructed at these rates in most cities in the recent past, indicating a need to pursue other methods to improve mobility.

Table S-4. Roadway Necessary to Maintain Constant Congestion Levels

Urban Area	Existing (1990) Lane-miles		Average Annual VMT Growth (%)[1]	Annual Additional Lane-Miles Needed		Rank[2]
	Freeway	Prin. Arter.		Freeway	Prin. Arter.	
Los Angeles CA	5,230	12,405	3.8	197	468	1
New York NY	5,900	7,560	3.4	201	257	2
Chicago IL	2,425	4,160	6.3	152	261	3
Phoenix AZ	625	3,120	6.3	39	196	4
San Diego CA	1,725	1,710	5.7	99	98	5
St. Louis MO	1,695	1,800	5.3	89	95	6
Miami FL	605	2,075	6.1	37	126	7
Cleveland OH	1,100	1,120	6.8	75	76	8
San Bernardino-Riv CA	895	2,140	4.4	39	94	9
San Fran-Oak CA	2,390	2,290	2.7	64	62	10

[1]Average Annual Growth rate of Freeway and Principal Arterial Streets DVMT between 1987-1990
[2]Ranked by total of freeway and principal arterial street lane-miles.

See Table 8 for complete listing of urban areas.
Source: TTI Analysis

The urban areas with the highest congestion costs are shown in Table S-5. The total congestion costs are comprised of delay and fuel costs. The delay and fuel costs have components related to the type of delay (recurring or incident) that occurs in the urban area. Los Angeles and New York had the highest total congestion costs with values of \$7.67 billion and \$6.56 billion, respectively. The tenth urban area in the table, Seattle-Everett, had a total congestion cost of \$1.14 billion.

Table S-5. Component and Total Congestion Costs By Urban Area for 1990

Urban Area	Annual Cost Due to Congestion ($Millions)					Rank
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost	
Los Angeles CA	3,000	3,530	530	620	7,680	1
New York NY	1,950	3,630	350	640	6,570	2
San Fran-Oak CA	1,050	1,330	190	240	2,810	3
Washington DC	760	1,260	130	220	2,370	4
Chicago IL	900	1,040	160	190	2,290	5
Houston TX	600	810	100	140	1,650	6
Detroit MI	510	800	80	130	1,520	7
Boston MA	330	910	60	160	1,460	8
Philadelphia PA	430	570	70	90	1,160	9
Seattle-Everett WA	420	550	70	100	1,140	10

See Table 16 for complete listing of urban areas.
Source: TTI Analysis and Local Transportation Agency Reference

Congestion costs can be used in relation to registered vehicles to show the economic impact on each automobile in the urban area. Table S-6 lists the top ten congestion costs per registered vehicle for 1990. Washington D.C. ranks first with a cost of $1,420 per vehicle. Dallas and Houston each have costs of $750 per vehicle, or approximately $3 per workday.

Table S-6. 1990 Congestion Cost per Registered Vehicle

Urban Area	Congestion Cost Per Registered Vehicle	Rank
Washington DC	$1,420	1
San Bernardino-Riv. CA	$1,320	2
New York NY	$1,090	3
Los Angeles CA	$ 980	4
San Jose CA	$ 960	5
San Fran-Oak CA	$ 930	6
Boston MA	$ 880	7
Seattle-Everett WA	$ 880	8
Dallas TX	$ 750	9
Houston TX	$ 750	10

See Table 17 for complete listing of urban areas

Source: TTI Analysis

Expressing congestion costs on a per capita basis illustrates the congestion "tax" paid by residents (Table S-7). The highest 1990 cost per capita occurred in San Bernardino-Riverside with a cost per capita of $880. Miami had the smallest cost per capita of the top ten urban areas with a cost of approximately $2 per capita for each workday.

Table S-7. 1990 Congestion Cost per Capita

Urban Area	Congestion Cost Per Capita	Rank
San Bernardino-Riv CA	$ 880	1
Washington DC	$ 770	2
San Fran-Oak CA	$ 760	3
San Jose CA	$ 690	4
Los Angeles CA	$ 670	5
Seattle-Everett WA	$ 660	6
Dallas TX	$ 570	7
Houston TX	$ 570	8
Atlanta GA	$ 530	9
Miami FL	$ 520	10

See Table 17 for complete listing of urban areas
Source: TTI Analysis

By arranging the urban areas into groups based on characteristics such as population size, it is possible to view the effects of congestion on the different groups of areas in the study. Table S-8 shows the vehicle hours of delay present in the study areas. The largest group (Chicago, Los Angeles, New York) has vehicle delay of at least 110 hours per person annually. The smallest group, comprised of areas with populations of 800,000 or less, has vehicle delay of 50 hours per person. This seems to indicate that the average congestion impact is twice as large on the average resident of a city with a population greater than 7 million than in the group of the smallest cities in our study.

Table S-8. 1990 Vehicle Delay for Population Groups

Population Group	Average Delay (Vehicle-hours)	Total Delay per 1000 Persons (Veh-Hours)
Fifth Group	1,272,570	110
Fourth Group	302,520	100
Third Group	141,830	90
Second Group	65,050	60
First Group	31,510	50

Source: TTI Analysis

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INTRODUCTION

Congestion within the inner city has long been recognized as a severe problem. Congested streets and freeways have forced residents and businesses to relocate in the surrounding suburbs. Relocating to the suburbs, however, proved to be only a temporary solution to metropolitan area congestion problems. Congestion has expanded into the suburbs, with street systems designed for service to residential areas overburdened with traffic headed to large shopping malls and business parks. Urban transportation systems have been required to serve more travel needs between suburbs and fewer trips to or from downtown business districts.

The decline in urban mobility resulting from congestion has become a major concern not only to the transportation community, but also to the motoring public and business community. Measuring congestion provides an understanding of the phenomenon which assists transportation professionals, policy makers, and the general public in effectively communicating problems and developing necessary transportation system improvements.

Purpose of Congestion Research

Why should we research and investigate effects of urban congestion? Quite simply, old solutions are not working any more. In the past, the mobility situation in most metropolitan areas has had the limited choices of controlling area growth, large expenditures for general use and transit facility improvements, or accepting decline in the quality of transportation in the cities and suburbs. Transportation professionals, policy makers, the media, and the general public generally view these options as undesirable. In more recent years, cities have encouraged the use of various aspects of travel demand management (TDM). Some of these techniques reduce vehicle-miles of travel, thus reducing congestion, while others only modify demand by shifting the time of travel.

Whether cities use more traditional techniques of congestion management or the more recent techniques such as TDM, measuring congestion is still a vital step in understanding the problems of congestion and aiding in the development of effective solutions to the urban mobility problem.

Previous research efforts of this series developed a quantitative procedure to compare traffic volumes and roadway mileage. The procedure estimates the mobility levels within an urban area and permits the comparison of transportation systems from year to year and area to area.

Congestion Research Background

This research study uses existing data from federal, state, and local agencies to develop planning estimates of the level of mobility within an urban area. The analyses presented in this report are the result of previous research (1-6) conducted at the Texas Transportation Institute. The methodology developed by the previous research provides a procedure which yields a quantitative estimate of urbanized area mobility levels, utilizing generally available data, while minimizing the need for extensive data collection.

The methodology primarily uses the Federal Highway Administration's Highway Performance Monitoring System (HPMS) database with supporting information from various state and local agencies. Currently, the database developed for this research contains vehicle travel, population, urban area size, and facility mileage from 1982 to 1990. Primarily, vehicle travel and vehicle travel per lane-mile are used as the basis of measuring urban mobility and comparing areawide roadway systems.

Report Organization/Content

There have been some changes incorporated in this report that differentiate it from others in this series (3,4,5,6). Recent congestion reports (3,4,5) contained detailed discussions of development for both the roadway congestion index (RCI) and cost methodology, including extensive appendices containing data compiled during the study. This research report will focus on the results of analyses estimating 1990 congestion levels and trends displayed by the data from 1982 to 1990. In addition, the metropolitan areas in the study have been grouped by such factors as population, land area, and population density to display trends that exist between these various groups. Information on the methodology is available in the previous reports.

This report summarizes and discusses urban mobility levels in 50 metropolitan areas throughout the United States. Seven of the areas studied represent the largest metropolitan areas in Texas; the remaining 43 areas are located in 27 states (Figure 1). These 50 areas include nearly all of the urban areas in the United States with populations of 800,000 or more that have a significant amount of congestion. Figure 1 illustrates the geographic regions used in the analyses to combine urban areas studied. There are three major topics addressed in this report: areawide mobility, the impacts of congestion, and the cost of congestion. The following are brief descriptions of the information included within each of these topics.

Areawide Mobility

Understanding the reasons for the type and scope of urban congestion problem has become important to transportation planners and policy makers. Obtaining quantitative estimates of mobility levels that allow the comparisons of transportation systems provides a tool to analyze the differences between different transportation systems and urban areas. This section discusses the trends in urban development, travel and mileage statistics, and the 1990 Roadway Congestion Index (RCI) values for 50 urban areas included within the study.

Impacts of Congestion

The most quantifiable impacts of congestion are additional capacity required to eliminate congested conditions and the amount of time spent by motorists in congestion. This section discusses the relationship between the freeway and principal arterial street systems and annual traffic growth. Travel delays are also addressed in this section. Delay, the most apparent impact of congestion to the motoring public, may be categorized into two general areas -- recurring and incident. The impacts of travel delay and the relationship with an urban area's RCI are analyzed.

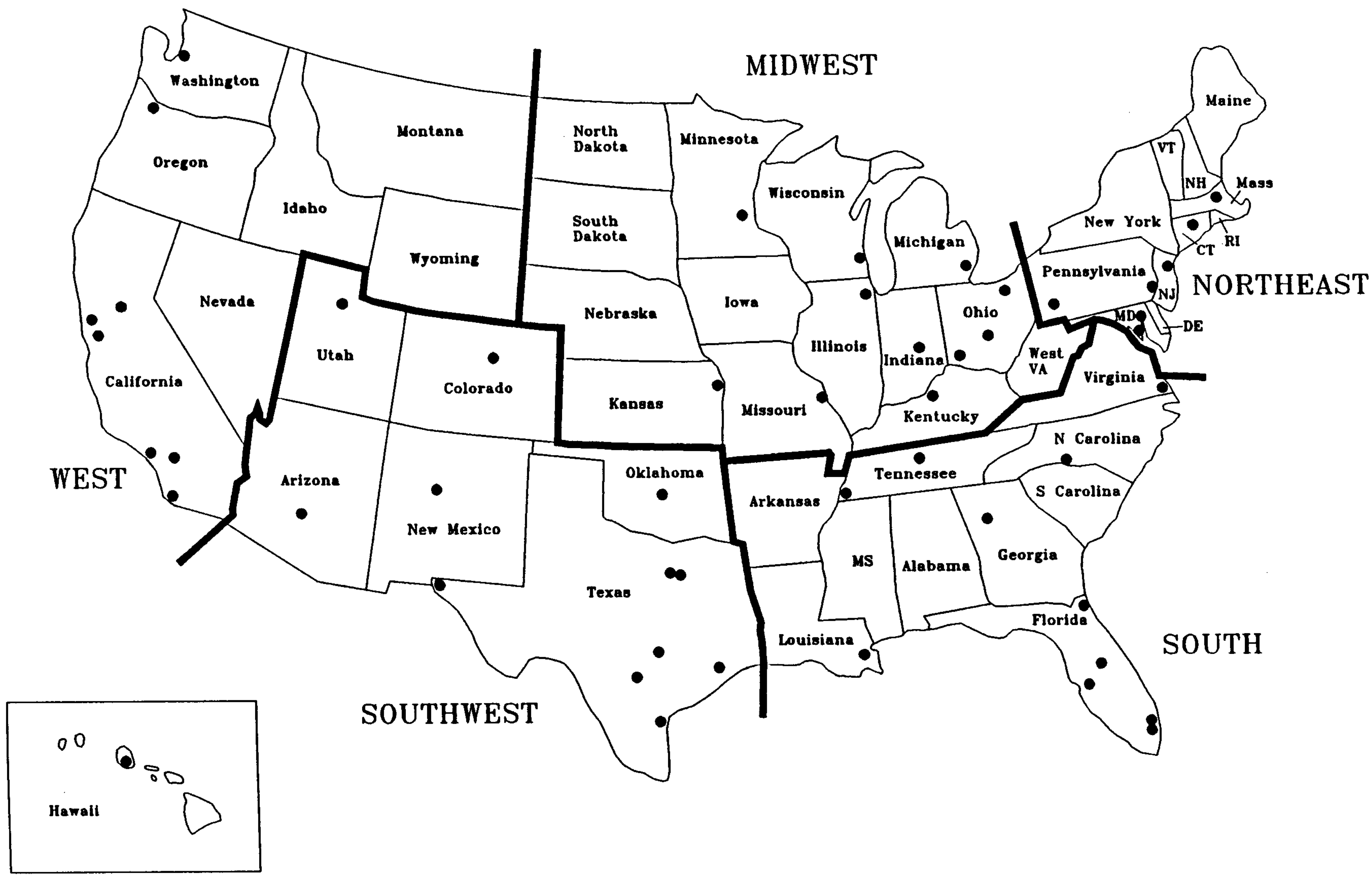

Figure 1. Regional Area Map

Cost of Congestion

Within this section the economic impact of congestion was estimated for the 50 urban areas studied. Congestion costs have two components -- delay and wasted fuel. Estimating the costs associated with congestion provides another tool for comparing urban mobility from one area to another. More importantly estimating congestion costs allows a method of tracking changes in congestion levels and their impact on an urbanized area over an extended period of time.

AREAWIDE MOBILITY

A 1989 report (7) identified several trends shaping traffic congestion. The interrelated forces impacting the nature and severity of congestion identified in that report include: (1) suburban development, (2) the economy, (3) the labor force, (4) automobile usage, (5) percent of truck traffic, and (6) the highway infrastructure. The following is an example of how these forces interact:

> "Trends in suburban and economic development have supported and generated increased automobile usage and truck traffic. This has resulted in increasing traffic congestion in many metropolitan areas throughout the country" (7).

Trends in Urban Development

Most metropolitan areas have experienced dynamic suburban growth since the 1960s. Suburban development was encouraged by the prevailing desire to live away from the inner city and yet be in close enough proximity to enjoy urban amenities. This evolutionary process begins with families and then expands to commercial services and jobs. The process shapes traffic congestion in most large and small metropolitan areas by altering the commuting patterns.

The demands placed on the existing highway infrastructure in general and by the migration of the population and employment opportunities have not been met by new facility construction. Demands for suburban traffic movement, increasing vehicle-miles of travel, and more freeway access points have greatly altered the function of the freeway/expressway system in most metropolitan areas. Increases in delay are the result of the roadway system capacity not increasing to meet new demands.

The decline in new facility construction during the past 20 years may be attributed to reduced funding, increased construction costs, and public resistance to building and widening transportation facilities. These factors have promoted lower levels of mobility and greater dispersion of the metropolitan area's population. In recent years, an increasingly negative perception of the mobility level has renewed interest in the transportation infrastructure. This same perception of the transportation infrastructure has also increased the desire of the transportation community, general public, policy makers, and numerous others to understand the causes, effects, and solutions to urban congestion.

Travel and Mileage Statistics

Previous TTI research (3,4,5,6) used daily vehicle-miles of travel (DVMT) per lane-mile of freeway and principal arterial street as indicators of urban congestion levels. The previous studies established the values of 13,000 DVMT per freeway lane-mile and 5,000 DVMT per (principal arterial street) lane-mile as the thresholds for undesirable congestion levels. Briefly, when areawide freeway travel volumes exceed an average of 13,000 DVMT per lane-mile, undesirable levels of congestion occur. The corresponding level of service is reached on principal arterial streets when travel volumes average 5,000 DVMT per lane-mile.

This section presents comparisons of mobility within geographic regions and between individual urban areas using DVMT per lane-mile statistics.

Freeway Travel and Mileage Statistics

Areawide freeway operating statistics are summarized in Table 1. The urban areas are ranked according to the primary congestion indicator, DVMT per lane-mile. Summary statistics for each geographical region are located at the bottom of Table 1.

Eighteen urbanized areas exceeded the 13,000 DVMT per lane-mile level indicating areawide congested conditions on the freeway systems. Of the ten urban areas with the highest DVMT per lane-mile values, five have experienced congested freeway systems since 1982. An additional eleven urban areas studied have DVMT per lane-mile values within ten percent of the 13,000 level. Urban areas with travel demands in this range would only have to experience moderate to slight increases in travel demands to cause their freeway systems to operate under congested conditions.

Table 1. 1990 Freeway Mileage and Travel Volume

Urban Area	DVMT[1] (1000)	Lane-Miles	Avg. No. Lanes	DVMT/[2] Ln-Mile	Rank[3]
Los Angeles CA	110,350	5,230	8.2	21,100	1
San Fran-Oak CA	42,590	2,390	6.8	17,820	2
Washington DC	25,340	1,530	5.3	16,610	3
San Bernardino-Riv CA	14,580	900	7.1	16,290	4
San Diego CA	27,690	1,730	7.4	16,050	5
Chicago IL	38,030	2,430	5.7	15,680	6
Seattle-Everett WA	18,920	1,210	6.0	15,640	7
Houston TX	28,230	1,920	6.3	14,700	8
Boston MA	21,610	1,520	5.9	14,220	9
Atlanta GA	24,260	1,710	6.1	14,190	10
Miami FL	8,570	610	5.4	14,170	11
New York NY	82,920	5,900	5.6	14,050	12
Dallas TX	23,680	1,710	5.9	13,850	13
New Orleans LA	4,970	360	5.8	13,810	14
San Jose CA	15,780	1,160	6.6	13,600	15
Honolulu HI	4,620	340	5.2	13,590	16
Portland OR	7,470	560	5.1	13,460	17
Detroit MI	22,650	1,700	5.8	13,320	18
Milwaukee WI	7,690	600	5.6	12,920	19
Denver CO	11,270	890	5.2	12,730	20
Baltimore MD	15,800	1,250	5.4	12,640	21
Cincinnati OH	11,380	910	5.7	12,570	22
Cleveland OH	13,700	1,100	4.7	12,450	23
Sacramento CA	9,260	750	6.9	12,350	24
Phoenix AZ	7,670	630	5.6	12,270	25
Philadelphia PA	18,330	1,510	5.1	12,140	26
Tampa FL	3,630	300	4.9	12,100	27
Austin TX	5,440	450	5.6	12,090	28
Minn-St. Paul MN	17,790	1,480	4.9	12,020	29
Jacksonville FL	5,380	450	4.6	11,960	30
Ft. Lauderdale FL	7,110	600	5.4	11,840	31
Norfolk VA	5,450	470	4.6	11,720	32
Fort Worth TX	11,840	1,020	5.8	11,610	33
St. Louis MO	19,120	1,700	5.5	11,280	34
San Antonio TX	9,280	830	5.3	11,250	35
Albuquerque NM	2,400	220	5.0	11,160	36
Memphis TN	4,340	390	5.4	11,130	37
Hartford CT	6,230	580	5.5	10,730	38
Indianapolis IN	8,050	760	5.3	10,590	39
Louisville KY	6,200	590	4.6	10,500	40
Salt Lake City UT	5,330	510	5.6	10,450	41
Columbus OH	8,350	800	5.8	10,440	42
Nashville TN	5,000	490	4.6	10,200	43
Orlando FL	5,950	590	4.9	10,080	44
Oklahoma City OK	6,940	720	5.1	9,630	45
El Paso TX	3,330	350	5.2	9,510	46
Kansas City MO	12,560	1,360	4.4	9,230	47
Corpus Christi TX	1,560	190	5.4	8,430	48
Pittsburgh PA	8,200	1,000	4.3	8,200	49
Charlotte NC	2,300	300	4.2	7,670	50
Northeastern Avg	25,490	1,900	5.3	12,660	
Midwestern Avg	14,370	1,180	5.3	11,720	
Southern Avg	7,000	570	5.1	11,710	
Southwestern Avg	10,000	790	5.5	11,640	
Western Avg	27,920	1,580	6.6	15,540	
Texas Avg	11,910	920	5.6	11,630	
Total Avg	15,780	1,130	5.5	12,520	
Maximum Value	110,350	5,900	8.2	21,100	
Minimum Value	1,560	190	4.2	7,670	

Note: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of freeway
[3] Rank value of 1 associated with most congested condition
Ranked by DVMT/Lane-mile

Source: TTI Analysis and Local Transportation Agency References

The summary statistics at the bottom of Table 1 show average DVMT per lane-mile values by geographic region. Every region (except the Western region) has DVMT per lane-mile values below the 13,000 level. Comparing these statistics with the similar 1989 analysis (6) shows that the average DVMT per lane-mile value for every geographic region (except Southern) has increased from one to two percent. Over the same period the Southern DVMT per lane-mile average has decreased slightly (less than one percent).

Principal Arterial Street Travel and Mileage Statistics

Table 2 shows the operating characteristics of the principal arterial street system for each urban area included in this study. As in Table 1, Table 2 ranks urban areas by travel demand per lane-mile and contains regional summary statistics. In 1990, 34 of the urban areas studied experienced DVMT per lane-mile levels exceeding 5,000. Of these 34 urban areas, 27 have had travel demands exceeding 5,000 DVMT per lane-mile since 1982.

The summary statistics show that all the regional averages except the Texas average exceed the 5,000 DVMT per lane-mile level. In contrast to the freeway values, the arterial street statistics indicate more congested operation on the arterial street systems in this study. The regional average travel demand on principal arterial street systems increased between one and three percent from 1989 levels in all of the geographic regions studied, except Texas. Urban areas in Texas showed no change in travel demand from 1989.

Table 2. 1990 Principal Arterial Street Mileage and Travel Volume

Urban Area	DVMT[1] (1000)	Lane-Miles	Avg. No. Lanes	DVMT/[2] Ln-Mile	Rank[3]
Washington DC	19,560	2,300	4.0	8,500	1
Honolulu HI	1,570	200	3.8	7,860	2
Miami FL	15,810	2,080	4.3	7,620	3
St. Louis MO	12,960	1,800	3.2	7,200	4
Chicago IL	29,050	4,160	3.7	6,980	5
New York NY	52,060	7,560	3.4	6,890	6
Tampa FL	4,360	660	3.8	6,610	7
Philadelphia PA	21,390	3,250	3.1	6,580	8
New Orleans LA	4,100	630	4.2	6,560	9
Los Angeles CA	80,370	12,410	4.0	6,480	10
Portland OR	3,710	580	3.3	6,400	11
Sacramento CA	7,000	1,100	4.0	6,360	12
Detroit MI	22,880	3,600	4.4	6,350	13
Atlanta GA	9,780	1,570	3.7	6,230	14
San Fran-Oak CA	14,000	2,290	3.9	6,110	15
Pittsburgh PA	10,910	1,820	3.2	5,990	16
Baltimore MD	9,850	1,660	4.1	5,930	17
Hartford CT	3,750	640	3.7	5,910	18
Denver CO	10,900	1,850	3.9	5,890	19
Seattle-Everett WA	9,130	1,580	3.4	5,800	20
Nashville TN	5,440	940	3.3	5,790	21
Norfolk VA	4,260	740	3.5	5,790	21
Charlotte NC	3,090	540	3.0	5,770	23
Salt Lake City UT	2,040	360	3.6	5,730	24
Louisville KY	2,950	520	3.6	5,660	25
Phoenix AZ	17,610	3,120	4.1	5,640	26
San Diego CA	9,340	1,710	3.4	5,460	27
Oklahoma City OK	3,590	680	3.2	5,270	28
Albuquerque NM	3,790	720	3.7	5,260	29
Memphis TN	4,240	810	4.3	5,230	30
Columbus OH	3,180	610	3.3	5,210	31
Ft. Lauderdale FL	5,800	1,120	4.3	5,200	32
Cleveland OH	5,790	1,120	3.0	5,170	33
Houston TX	10,830	2,130	4.3	5,080	34
Fort Worth TX	4,240	870	4.1	4,870	35
Austin TX	2,090	430	4.2	4,860	36
Dallas TX	8,310	1,710	4.8	4,860	36
San Jose CA	6,780	1,400	4.2	4,860	36
Jacksonville FL	5,810	1,200	3.7	4,840	39
San Antonio TX	5,240	1,090	3.5	4,810	40
Milwaukee WI	4,780	1,010	3.4	4,760	41
San Bernardino-Riv CA	10,150	2,140	4.2	4,740	42
Minn-St. Paul MN	5,640	1,200	3.3	4,700	43
Corpus Christi TX	1,500	330	3.9	4,620	44
Boston MA	12,540	2,760	2.3	4,540	45
Kansas City MO	4,810	1,060	3.5	4,540	45
Indianapolis IN	3,970	880	3.7	4,510	47
Cincinnati OH	3,670	820	3.3	4,480	48
El Paso TX	3,200	840	4.2	3,830	49
Orlando FL	3,850	1,570	3.7	2,450	50
Northeastern Avg	18,580	2,860	3.4	6,340	
Midwestern Avg	8,600	1,450	3.5	5,400	
Southern Avg	6,050	1,080	3.8	5,640	
Southwestern Avg	6,340	1,220	4.0	5,040	
Western Avg	15,780	2,600	3.8	6,010	
Texas Avg	5,060	1,060	4.1	4,700	
Total Avg	10,230	1,720	3.7	5,620	
Maximum Value	80,370	12,410	4.8	8,500	
Minimum Value	1,500	200	2.3	2,450	

Notes: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of principal arterial
[3] Rank value of 1 associated with most congested condition ranked by DVMT/Lane-mile

Source: TTI Analysis and Local Transportation Agency References

Relationship Between Travel Demand and Urban Area Population/Size

In previous reports (4,5,6), reference was made to relationships of DVMT and facility lane-miles to urban area population and size. The relationship between travel demand, lane-miles, and population indicates on what facilities motorists place the highest demand, while the relationship between DVMT, facility lane-miles, and area size indicates the density of both the freeway and principal arterial street systems.

Tables 3 and 4 show the relationship between DVMT and urban area population. In both tables, the urban areas are ranked by DVMT and facility lane-miles per person. Comparison of the summary statistics of these tables indicates:

- The DVMT per person value shows each geographic region studied depends on the freeway system for service of the majority of travel demand.
- The freeway systems in the Texas region and the principal arterial street systems in the Southern region are the most dense across the regions.
- The greatest travel per capita occurs on the freeways in the Western region and on the principal arterial street system in the Southern region.

Roadway Congestion Index Values, 1990

Table 5 combines the freeway and principal arterial street system DVMT and DVMT per lane-mile values into the estimated 1990 Roadway Congestion Index (RCI). Equation 1 illustrates how those values are used to calculate the RCI value for individual urban areas. The RCI value is a relative measure of the level of congestion for a given urban area. An RCI value of 1.0 or greater indicates an undesirable areawide congestion level.

$$\text{Roadway Congestion Index} = \frac{\left[\text{Freeway VMT/Ln.-Mi.} \times \text{Freeway VMT} + \text{Prin Art Str VMT/Ln.-Mi.} \times \text{Prin Art Str VMT}\right]}{\left[13{,}000 \times \text{Freeway VMT} + 5{,}000 \times \text{Prin Art Str VMT}\right]} \qquad \text{Eq. 1}$$

Table 3. Freeway Travel Frequency and Density Statistics for 1990

Urban Area	Popn. (1000)	Urban Area (Sq.Mi)	Popn Density Pers/Sq Mi	DVMT[1] Per Person	Rank[3]	Ln Mi[2] Per 1000 Pers	Rank[3]
Northeastern Cities							
Baltimore MD	1,990	550	3,620	7.94	23	0.63	22
Boston MA	2,960	1,070	2,760	7.31	28	0.51	16
Hartford CT	610	360	1,690	10.20	10	0.95	48
New York NY	16,780	3,190	5,270	4.94	44	0.35	5
Philadelphia PA	4,220	1,130	3,730	4.34	49	0.36	6
Pittsburgh PA	1,870	740	2,520	4.39	48	0.54	18
Washington DC	3,100	840	3,690	8.17	22	0.49	14
Midwestern Cities							
Chicago IL	7,510	1,990	3,770	5.06	42	0.32	1
Cincinnati OH	1,140	570	2,000	9.98	11	0.79	38
Cleveland OH	1,790	650	2,780	7.65	25	0.61	21
Columbus OH	850	310	2,740	9.82	13	0.94	47
Detroit MI	4,000	1,260	3,190	5.66	37	0.43	8
Indianapolis IN	950	440	2,150	8.52	20	0.80	39
Kansas City MO	1,160	610	1,900	10.82	8	1.17	50
Louisville KY	810	380	2,130	7.65	25	0.73	34
Milwaukee WI	1,230	550	2,240	6.25	34	0.48	13
Minn-St. Paul MN	2,010	1,020	1,970	8.85	18	0.74	35
Oklahoma City OK	740	500	1,470	9.44	17	0.98	49
St. Louis MO	1,960	730	2,680	9.76	15	0.86	42
Southern Cities							
Atlanta GA	1,880	1,550	1,210	12.94	1	0.91	46
Charlotte NC	450	240	1,880	5.11	41	0.67	28
Ft. Lauderdale FL	1,270	430	2,950	5.59	38	0.47	12
Jacksonville FL	720	540	1,330	7.47	27	0.63	22
Memphis TN	860	430	2,020	5.05	43	0.45	10
Miami FL	1,850	480	3,850	4.63	45	0.33	2
Nashville TN	570	500	1,130	8.85	18	0.87	44
New Orleans LA	1,080	360	3,000	4.60	46	0.33	2
Norfolk VA	930	820	1,130	5.89	36	0.50	15
Orlando FL	850	410	2,070	7.00	31	0.69	31
Tampa FL	700	450	1,570	5.19	40	0.43	8
Southwestern Cities							
Albuquerque NM	530	260	2,060	4.57	47	0.41	7
Austin TX	510	350	1,460	10.67	9	0.88	45
Corpus Christi TX	280	180	1,600	5.57	39	0.66	27
Dallas TX	1,990	1,440	1,380	11.90	4	0.86	42
Denver CO	1,580	890	1,780	7.13	30	0.56	20
El Paso TX	540	210	2,570	6.17	35	0.65	25
Fort Worth TX	1,200	850	1,410	9.87	12	0.85	41
Houston TX	2,880	1,640	1,760	9.80	14	0.67	28
Phoenix AZ	1,900	980	1,940	4.05	50	0.33	2
Salt Lake City UT	800	470	1,700	6.66	33	0.64	24
San Antonio TX	1,170	490	2,410	7.93	24	0.71	33
Western Cities							
Honolulu HI	660	140	4,890	7.00	31	0.52	17
Los Angeles CA	11,420	2,190	5,230	9.66	16	0.46	11
Portland OR	1,030	420	2,450	7.25	29	0.54	18
Sacramento CA	1,100	360	3,040	8.46	21	0.68	30
San Bernardino-Riv CA	1,170	490	2,390	12.46	2	0.76	37
San Diego CA	2,300	710	3,230	12.07	3	0.75	36
San Fran-Oak CA	3,680	850	4,350	11.59	5	0.65	25
San Jose CA	1,410	450	3,130	11.19	6	0.83	40
Seattle-Everett WA	1,730	730	2,390	10.94	7	0.70	32
Northeastern Avg	4,500	1,130	3,330	6.76		0.55	
Midwestern Avg	2,010	750	2,420	8.29		0.74	
Southern Avg	1,010	560	2,010	6.57		0.57	
Southwestern Avg	1,220	700	1,820	7.67		0.66	
Western Avg	2,720	700	3,460	10.07		0.65	
Texas Avg	1,220	740	1,800	8.84		0.75	
Total Avg	2,090	740	2,510	7.88		0.64	
Maximum Value	16,780	3,190	5,270	12.94		1.17	
Minimum Value	280	140	1,130	4.05		0.32	

Notes: [1] Daily vehicle-miles of travel per person
[2] Lane-miles per 1000 persons
[3] Rank value of 1 associated with most congested condition

Source: TTI Analysis and Local Transportation Agency References

Table 4. Principal Arterial Street Travel Frequency and Density Statistics for 1990

Urban Area	Popn. (1000)	Urban Area (Sq.Mi)	Popn Density Pers/Sq Mi	DVMT[1] Per Person	Rank[3]	Ln Mi[2] Per 1000 Pers	Rank[3]
Northeastern Cities							
Baltimore MD	1,990	550	3,620	4.95	22	0.83	20
Boston MA	2,960	1,070	2,760	4.24	30	0.93	29
Hartford CT	610	360	1,690	6.15	14	1.04	38
New York NY	16,780	3,190	5,270	3.10	47	0.45	3
Philadelphia PA	4,220	1,130	3,730	5.07	21	0.77	17
Pittsburgh PA	1,870	740	2,520	5.85	16	0.98	35
Washington DC	3,100	840	3,690	6.31	12	0.74	14
Midwestern Cities							
Chicago IL	7,510	1,990	3,770	3.87	37	0.55	4
Cincinnati OH	1,140	570	2,000	3.22	46	0.72	11
Cleveland OH	1,790	650	2,780	3.23	45	0.63	9
Columbus OH	850	310	2,740	3.74	41	0.72	11
Detroit MI	4,000	1,260	3,190	5.72	17	0.90	25
Indianapolis IN	950	440	2,150	4.20	31	0.93	29
Kansas City MO	1,160	610	1,900	4.15	33	0.91	26
Louisville KY	810	380	2,130	3.64	42	0.64	10
Milwaukee WI	1,230	550	2,240	3.89	36	0.82	19
Minn-St. Paul MN	2,010	1,020	1,970	2.81	48	0.60	7
Oklahoma City OK	740	500	1,470	4.88	24	0.93	29
St. Louis MO	1,960	730	2,680	6.61	10	0.92	28
Southern Cities							
Atlanta GA	1,880	1,550	1,210	5.22	20	0.84	21
Charlotte NC	450	240	1,880	6.86	9	1.19	43
Ft. Lauderdale FL	1,270	430	2,950	4.57	27	0.88	24
Jacksonville FL	720	540	1,330	8.06	5	1.67	48
Memphis TN	860	430	2,020	4.92	23	0.94	33
Miami FL	1,850	480	3,850	8.54	4	1.12	40
Nashville TN	570	500	1,130	9.63	1	1.66	47
New Orleans LA	1,080	360	3,000	3.80	39	0.58	6
Norfolk VA	930	820	1,130	4.60	26	0.79	18
Orlando FL	850	410	2,070	4.53	28	1.85	50
Tampa FL	700	450	1,570	6.23	13	0.94	33
Southwestern Cities							
Albuquerque NM	530	260	2,060	7.22	6	1.37	44
Austin TX	510	350	1,460	4.10	34	0.84	21
Corpus Christi TX	280	180	1,600	5.43	18	1.16	41
Dallas TX	1,990	1,440	1,380	4.18	32	0.86	23
Denver CO	1,580	890	1,780	6.90	8	1.17	42
El Paso TX	540	210	2,570	5.93	15	1.55	45
Fort Worth TX	1,200	850	1,410	3.53	44	0.73	13
Houston TX	2,880	1,640	1,760	3.76	40	0.74	14
Phoenix AZ	1,900	980	1,940	9.29	2	1.65	46
Salt Lake City UT	800	470	1,700	2.54	49	0.44	2
San Antonio TX	1,170	490	2,410	4.48	29	0.93	29
Western Cities							
Honolulu HI	660	140	4,890	2.38	50	0.30	1
Los Angeles CA	11,420	2,190	5,230	7.04	7	1.09	39
Portland OR	1,030	420	2,450	3.60	43	0.56	5
Sacramento CA	1,100	360	3,040	6.39	11	1.00	37
San Bernardino-Riv CA	1,170	490	2,390	8.68	3	1.83	49
San Diego CA	2,300	710	3,230	4.07	35	0.75	16
San Fran-Oak CA	3,680	850	4,350	3.81	38	0.62	8
San Jose CA	1,410	450	3,130	4.80	25	0.99	36
Seattle-Everett WA	1,730	730	2,390	5.28	19	0.91	26
Northeastern Avg	4,500	1,130	3,330	5.10		0.82	
Midwestern Avg	2,010	750	2,420	4.16		0.77	
Southern Avg	1,010	560	2,010	6.09		1.13	
Southwestern Avg	1,220	700	1,820	5.21		1.04	
Western Avg	2,720	700	3,460	5.12		0.89	
Texas Avg	1,220	740	1,800	4.49		0.97	
Total Avg	2,090	740	2,510	5.12		0.94	
Maximum Value	16,780	3,190	5,270	9.63		1.85	
Minimum Value	280	140	1,130	2.38		0.30	

Notes: [1] Daily vehicle-miles of travel per person
[2] Lane-miles per 1000 persons
[3] Rank value of 1 associated

Source: TTI Analysis and Local Transportation Agency References

Table 5. 1990 Roadway Congestion Index Value

Urban Area	Freeway / Expressway DVMT[1] (1000)	Freeway / Expressway DVMT/[2] Ln-Mile	Principal Arterial Street DVMT[1] (1000)	Principal Arterial Street DVMT/[2] Ln-Mile	Roadway[3] Congestion Index	Rank
Los Angeles CA	110,350	21,100	80,370	6,480	1.55	1
Washington DC	25,340	16,610	19,560	8,500	1.37	2
San Fran-Oak CA	42,590	17,820	14,000	6,110	1.35	3
Miami FL	8,570	14,170	15,810	7,620	1.26	4
Chicago IL	38,030	15,680	29,050	6,980	1.25	5
San Diego CA	27,690	16,050	9,340	5,460	1.22	6
Seattle-Everett WA	18,920	15,640	9,130	5,800	1.20	7
San Bernardino-Riv CA	14,580	16,290	10,150	4,740	1.19	8
New York NY	82,920	14,050	52,060	6,890	1.14	9
Houston TX	28,230	14,700	10,830	5,080	1.12	10
New Orleans LA	4,970	13,810	4,100	6,560	1.12	10
Atlanta GA	24,260	14,190	9,780	6,230	1.11	12
Honolulu HI	4,620	13,590	1,570	7,860	1.11	12
Detroit MI	22,650	13,320	22,880	6,350	1.09	14
Portland OR	7,470	13,460	3,710	6,400	1.07	15
Boston MA	21,610	14,220	12,540	4,540	1.06	16
Dallas TX	23,680	13,850	8,310	4,860	1.05	17
Philadelphia PA	18,330	12,140	21,390	6,580	1.05	17
Tampa FL	3,630	12,100	4,360	6,610	1.05	17
San Jose CA	15,780	13,600	6,780	4,860	1.04	20
Denver CO	11,270	12,730	10,900	5,890	1.03	21
Phoenix AZ	7,670	12,270	17,610	5,640	1.03	21
Sacramento CA	9,260	12,350	7,000	6,360	1.02	23
Baltimore MD	15,800	12,640	9,850	5,930	1.01	24
Milwaukee WI	7,690	12,920	4,780	4,760	0.99	25
St. Louis MO	19,120	11,280	12,960	7,200	0.99	25
Cleveland OH	13,700	12,450	5,790	5,170	0.97	27
Cincinnati OH	11,380	12,570	3,670	4,480	0.96	28
Norfolk VA	5,450	11,720	4,260	5,790	0.96	28
Austin TX	5,440	12,090	2,090	4,860	0.94	30
Ft. Lauderdale FL	7,110	11,840	5,800	5,200	0.94	30
Jacksonville FL	5,380	11,960	5,810	4,840	0.94	30
Albuquerque NM	2,400	11,160	3,790	5,260	0.93	33
Minn-St. Paul MN	17,790	12,020	5,640	4,700	0.93	33
Memphis TN	4,340	11,130	4,240	5,230	0.91	35
Fort Worth TX	11,840	11,610	4,240	4,870	0.90	36
Hartford CT	6,230	10,730	3,750	5,910	0.89	37
Nashville TN	5,000	10,200	5,440	5,790	0.89	37
San Antonio TX	9,280	11,250	5,240	4,810	0.88	39
Louisville KY	6,200	10,500	2,950	5,660	0.86	40
Salt Lake City UT	5,330	10,450	2,040	5,730	0.85	41
Columbus OH	8,350	10,440	3,180	5,210	0.83	42
Indianapolis IN	8,050	10,590	3,970	4,510	0.83	42
Pittsburgh PA	8,200	8,200	10,910	5,990	0.82	44
Oklahoma City OK	6,940	9,630	3,590	5,270	0.79	45
Charlotte NC	2,300	7,670	3,090	5,770	0.78	46
El Paso TX	3,330	9,510	3,200	3,830	0.74	47
Kansas City MO	12,560	9,230	4,810	4,540	0.74	47
Corpus Christi TX	1,560	8,430	1,500	4,620	0.72	49
Orlando FL	5,950	10,080	3,850	2,450	0.72	49
Northeastern Avg	25,490	12,660	18,580	6,340	1.05	
Midwestern Avg	14,370	11,720	8,600	5,400	0.94	
Southern Avg	7,000	11,710	6,050	5,640	0.97	
Southwestern Avg	10,000	11,640	6,340	5,040	0.93	
Western Avg	27,920	15,540	15,780	6,010	1.19	
Texas Avg	11,910	11,630	5,060	4,700	0.91	
Total Avg	15,780	12,520	10,230	5,620	1.00	
Maximum Value	110,350	21,100	80,370	8,500	1.55	
Minimum Value	1,560	7,670	1,500	2,450	0.72	

Notes: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile
[3] See Equation 1

Source: TTI Analysis

1990 Roadway Congestion Index Estimates

Of the 50 urban areas studied, 24 have RCI values exceeding 1.0. RCI values for the ten most congested urban areas range from 1.55 (Los Angeles) to 1.12 (Houston and New Orleans). Twelve urban areas have estimated RCI values ranging between 0.99 and 0.90 indicating the potential approach of undesirable congestion levels. These areas may not currently experience undesirable levels of congestion, however, traffic growth rates indicate congestion levels could become undesirable within the next few years in many of these cities.

The Western region has the highest average RCI value of 1.19. The only other regional average exceeding 1.0 was the Northeastern (1.05). The Southwestern, Southern, and Midwestern regions have average RCI values below 1.0.

Houston (tied at 10th) was the only urban area studied in Texas which was included in the ten most congested urban areas. Dallas (tied at 17th) was the second highest ranked area within the state. Austin was ranked (tied at 30th) as the only other urbanized area in the state in the top 30.

Roadway Congestion Index Growth, 1982 to 1990

Roadway congestion index values for all 50 urban areas from 1982 to 1990 are summarized in Table 6. During the study period, San Diego, San Francisco, and Salt Lake City were estimated to have experienced the fastest increase in congestion, while Phoenix, Detroit, and Houston have experienced the smallest. Of the urban areas in Texas, Dallas has the largest increase in RCI from 1982 levels (25 percent). Approximately 40 percent of the urban areas have experienced between 17 and 23 percent growth between 1982 and 1990. The summary statistics show that no geographic region experienced a decrease in average 1990 RCI values from 1989 levels.

Figure 2 illustrates trend data for the Texas urban areas studied. This figure graphically shows the improving trend of congestion in Houston which is currently below 1982 levels. Dallas, Fort Worth, and Austin experienced increasing congestion levels until 1986. Since that time, congestion levels have been relatively constant. San Antonio, El Paso, and Corpus Christi exhibited a slightly increasing trend in their RCI values between 1987 and 1990.

Table 6. Roadway Congestion Index Values, 1982 to 1990

Urban Area	Year									Percent Change 1982 to 1990
	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Phoenix AZ	1.15	1.16	1.10	1.13	1.20	1.18	1.00	1.03	1.03	-10
Houston TX	1.17	1.21	1.25	1.23	1.21	1.19	1.15	1.13	1.12	-4
Detroit MI	1.13	1.10	1.13	1.12	1.11	1.10	1.09	1.08	1.09	-4
Louisville KY	0.84	0.82	0.81	0.79	0.80	0.88	0.87	0.86	0.86	2
Philadelphia PA	1.00	1.03	1.04	0.90	1.06	1.06	1.07	1.05	1.05	5
Pittsburgh PA	0.78	0.76	0.76	0.78	0.79	0.79	0.81	0.82	0.82	5
Memphis TN	0.86	0.80	0.76	0.75	0.77	0.84	0.86	0.91	0.91	6
Corpus Christi TX	0.67	0.69	0.69	0.71	0.71	0.72	0.70	0.71	0.72	7
Jacksonville FL	0.87	0.98	0.98	0.98	0.95	0.94	0.95	0.93	0.94	8
Orlando FL	0.66	0.68	0.67	0.71	0.71	0.72	0.74	0.72	0.72	9
San Bernardino-Riv CA	1.09	1.11	1.12	1.11	1.14	1.13	1.16	1.16	1.19	9
Ft. Lauderdale FL	0.86	0.85	0.84	0.84	0.84	0.90	0.90	0.92	0.94	9
Oklahoma City OK	0.72	0.72	0.75	0.74	0.71	0.76	0.78	0.78	0.79	10
Cincinnati OH	0.86	0.83	0.82	0.83	0.84	0.87	0.88	0.94	0.96	12
Tampa FL	0.94	0.91	1.03	1.00	0.96	1.02	1.03	1.03	1.05	12
New York NY	1.01	1.02	0.99	1.00	1.06	1.06	1.10	1.12	1.14	13
San Antonio TX	0.77	0.79	0.82	0.87	0.90	0.85	0.86	0.87	0.88	14
New Orleans LA	0.98	1.00	1.05	1.10	1.11	1.14	1.13	1.13	1.12	14
Charlotte NC	0.67	0.72	0.72	0.73	0.73	0.74	0.73	0.74	0.78	16
Indianapolis IN	0.71	0.66	0.75	0.76	0.80	0.85	0.84	0.85	0.83	17
Hartford CT	0.76	0.79	0.86	0.85	0.85	0.87	0.91	0.89	0.89	17
El Paso TX	0.63	0.64	0.65	0.70	0.75	0.71	0.74	0.74	0.74	17
Boston MA	0.90	0.93	0.95	0.98	1.04	1.04	1.12	1.09	1.06	18
Fort Worth TX	0.76	0.79	0.80	0.82	0.87	0.87	0.87	0.87	0.90	18
Albuquerque NM	0.78	0.83	0.89	0.93	0.88	0.91	0.90	0.91	0.93	19
Milwaukee WI	0.83	0.84	0.87	0.88	0.90	0.95	0.94	0.97	0.99	19
St. Louis MO	0.83	0.87	0.88	0.89	0.93	0.96	0.98	0.96	0.99	19
Kansas City MO	0.62	0.62	0.60	0.65	0.69	0.71	0.72	0.72	0.74	19
Honolulu HI	0.93	0.95	0.97	0.97	1.05	1.07	1.10	1.09	1.11	19
Miami FL	1.05	1.09	1.07	1.13	1.10	1.14	1.18	1.25	1.26	20
Baltimore MD	0.84	0.84	0.85	0.84	0.88	0.90	0.92	0.99	1.01	20
Nashville TN	0.74	0.76	0.83	0.81	0.86	0.88	0.94	0.90	0.89	20
Denver CO	0.85	0.88	0.93	0.96	0.97	0.95	0.99	1.01	1.03	21
Cleveland OH	0.80	0.82	0.83	0.81	0.86	0.89	0.97	0.95	0.97	21
Norfolk VA	0.79	0.77	0.79	0.84	0.90	0.93	0.94	0.95	0.96	22
Columbus OH	0.68	0.71	0.71	0.71	0.75	0.78	0.79	0.82	0.83	22
Austin TX	0.77	0.84	0.89	0.91	0.98	0.96	0.96	0.96	0.94	22
San Jose CA	0.85	0.87	0.90	0.94	0.96	0.98	0.99	1.02	1.04	22
Chicago IL	1.02	1.02	1.05	1.08	1.15	1.15	1.18	1.21	1.25	23
Portland OR	0.87	0.86	0.88	0.93	0.97	1.00	1.05	1.07	1.07	23
Atlanta GA	0.89	0.94	0.97	1.02	1.09	1.11	1.14	1.14	1.11	25
Dallas TX	0.84	0.89	0.94	0.98	1.04	1.02	1.02	1.02	1.05	25
Minn-St. Paul MN	0.74	0.79	0.81	0.83	0.87	0.87	0.88	0.90	0.93	26
Seattle-Everett WA	0.95	0.99	1.02	1.05	1.09	1.14	1.17	1.21	1.20	26
Los Angeles CA	1.22	1.27	1.32	1.36	1.42	1.47	1.52	1.54	1.55	27
Sacramento CA	0.80	0.84	0.88	0.92	0.95	1.00	1.03	1.01	1.02	27
Washington DC	1.07	1.09	1.12	1.20	1.28	1.30	1.32	1.36	1.37	28
San Fran-Oak CA	1.01	1.05	1.12	1.17	1.24	1.31	1.33	1.36	1.35	34
Salt Lake City UT	0.63	0.63	0.65	0.68	0.68	0.70	0.72	0.81	0.85	35
San Diego CA	0.78	0.83	0.91	0.95	1.00	1.08	1.13	1.18	1.22	56
Northeastern Avg	0.91	0.92	0.94	0.94	0.99	1.00	1.04	1.05	1.05	
Midwestern Avg	0.82	0.82	0.83	0.84	0.87	0.90	0.91	0.92	0.94	
Southern Avg	0.85	0.86	0.88	0.90	0.91	0.94	0.96	0.97	0.97	
Southwestern Avg	0.82	0.85	0.87	0.90	0.93	0.91	0.90	0.91	0.93	
Western Avg	0.94	0.97	1.01	1.04	1.09	1.13	1.16	1.18	1.19	
Texas Avg	0.80	0.84	0.86	0.89	0.92	0.90	0.90	0.90	0.91	
Total Avg	0.86	0.88	0.90	0.92	0.95	0.97	0.98	0.99	1.00	
Maximum Value	1.22	1.27	1.32	1.36	1.42	1.47	1.52	1.54	1.55	
Minimum Value	0.62	0.62	0.60	0.65	0.68	0.70	0.70	0.71	0.72	

Source: TTI Analysis

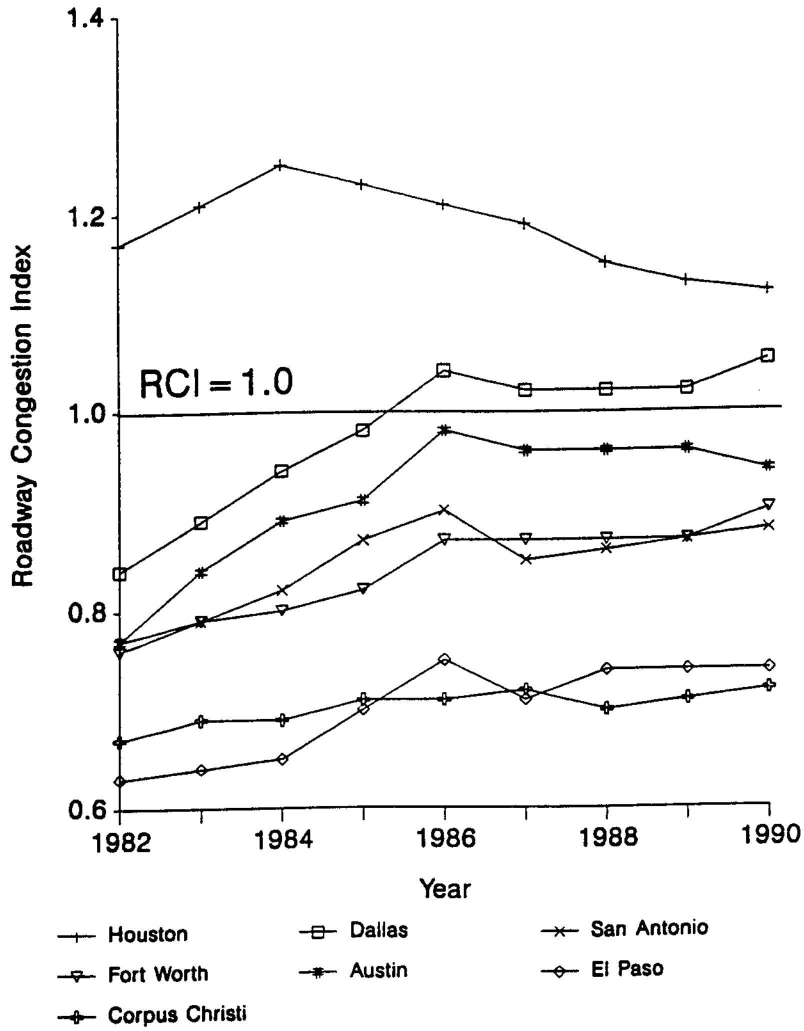

Figure 2. Texas Urban Area RCIs 1982 - 1990

IMPACTS OF CONGESTION

The most quantifiable impacts of congestion are additional capacity required to eliminate the congested conditions and the time spent in congested traffic conditions. Additional capacity required annually to maintain existing traffic density levels indicates the burden of congestion on the transportation infrastructure and available roadway funds. Travel delay is the measure of inconvenience congestion imposes on the motoring public.

Travel Volumes

Freeway and principal arterial street systems are the primary facilities selected for expansion because the majority (60 to 70 percent) of an urban area's DVMT is served by these facilities. Table 7 illustrates the percentage of daily VMT served by the freeway and principal arterial street systems. While the average amount of daily VMT served by these facilities is significant in all areas, comparing the percentage for each urban and geographic area (Table 7) does give some indication of the facility carrying the majority of the demand.

Figure 3 illustrates the regional daily VMT served by the freeway system for each geographical region studied. During the study period, the percentages have remained relatively constant for each region. Motorists in the Western region place the highest demand on the freeway system, while the Southern region places the lowest. Motorists in the Texas and Midwestern regions place the second highest average demand on the freeway system of all geographic regions.

Figure 4 shows the corresponding demands placed on the principal arterial street systems. This figure shows that the highest demand on the principal arterial street system is placed by the Northeastern and Southern regions. The Texas and Midwestern regions depend the least on this system for urban travel. Each of the regions have shown a decrease in the percentage of DVMT serviced by principal arterial streets from 1982 to 1990.

Table 7. 1990 Urban Area Travel by Facility Type

Urban Area	Daily Vehicle-Miles of Travel			Fwy/Expwy[1] % of Total	Prin.Art.Str.[1] % of Total	Fwy/Prin.Art.Str. % of Total
	Fwy/Expwy	Prin.Art.Str.	Area Total			
Northeastern Cities						
Baltimore MD	15,800	9,850	36,370	43	27	70
Boston MA	21,610	12,540	51,340	42	24	66
Hartford CT	6,230	3,750	13,900	45	27	72
New York NY	82,920	52,060	225,010	37	23	60
Philadelphia PA	18,330	21,390	65,760	28	33	61
Pittsburgh PA	8,200	10,910	32,470	25	34	59
Washington DC	25,340	19,560	64,320	39	30	69
Midwestern Cities						
Chicago IL	38,030	29,050	123,470	31	24	55
Cincinnati OH	11,380	3,670	24,040	47	15	62
Cleveland OH	13,700	5,790	32,970	42	18	60
Columbus OH	8,350	3,180	18,380	45	17	62
Detroit MI	22,650	22,880	78,220	29	29	58
Indianapolis IN	8,050	3,970	21,070	38	19	57
Kansas City MO	12,560	4,810	27,470	46	18	64
Louisville KY	6,200	2,950	17,670	35	17	52
Milwaukee WI	7,690	4,780	28,660	27	17	44
Minn-St. Paul MN	17,790	5,640	43,190	41	13	54
Oklahoma City OK	6,940	3,590	18,550	37	19	56
St. Louis MO	19,120	12,960	45,290	42	29	71
Southern Cities						
Atlanta GA	24,260	9,780	64,830	37	15	52
Charlotte NC	2,300	3,090	10,150	23	30	53
Ft. Lauderdale FL	7,110	5,800	24,300	29	24	53
Jacksonville FL	5,380	5,810	17,790	30	33	63
Memphis TN	4,340	4,240	16,130	27	26	53
Miami FL	8,570	15,810	33,530	26	47	73
Nashville TN	5,000	5,440	15,610	32	35	67
New Orleans LA	4,970	4,100	16,720	30	25	55
Norfolk VA	5,450	4,260	20,270	27	21	48
Orlando FL	5,950	3,850	17,730	34	22	56
Tampa FL	3,630	4,360	15,730	23	28	51
Southwestern Cities						
Albuquerque NM	2,400	3,790	10,240	23	37	60
Austin TX	5,440	2,090	12,000	45	17	62
Corpus Christi TX	1,560	1,500	6,550	24	23	47
Dallas TX	23,680	8,310	52,130	45	16	61
Denver CO	11,270	10,900	27,150	42	40	82
El Paso TX	3,330	3,200	9,460	35	34	69
Fort Worth TX	11,840	4,240	28,070	42	15	57
Houston TX	28,230	10,830	71,610	39	15	54
Phoenix AZ	7,670	17,610	39,650	19	44	63
Salt Lake City UT	5,330	2,040	15,170	35	13	48
San Antonio TX	9,280	5,240	25,320	37	21	58
Western Cities						
Honolulu HI	4,620	1,570	10,970	42	14	56
Los Angeles CA	110,350	80,370	250,670	44	32	76
Portland OR	7,470	3,710	19,400	39	19	58
Sacramento CA	9,260	7,000	23,620	39	30	69
San Bernardino-Riv CA	14,580	10,150	25,050	58	41	99
San Diego CA	27,690	9,340	51,610	54	18	72
San Fran-Oak CA	42,590	14,000	76,950	55	18	73
San Jose CA	15,780	6,780	32,450	49	21	70
Seattle-Everett WA	18,920	9,130	40,840	46	22	68
Northeastern Avg	25,490	18,580	69,880	37	28	65
Midwestern Avg	14,370	8,600	39,920	38	20	58
Southern Avg	7,000	6,050	22,980	29	28	57
Southwestern Avg	10,000	6,340	27,030	35	25	60
Western Avg	27,920	15,780	59,060	47	24	71
Texas Avg	11,910	5,060	29,300	38	20	58
Total Avg	15,780	10,230	41,000	37	25	62
Maximum Value	110,350	80,370	250,670	58	47	99
Minimum Value	1,560	1,500	6,550	19	13	44

Notes: [1] Percentage of Total Daily Vehicle-Miles of Travel serviced by specified facility

Source: TTI Analysis and Local Transportation Agency References

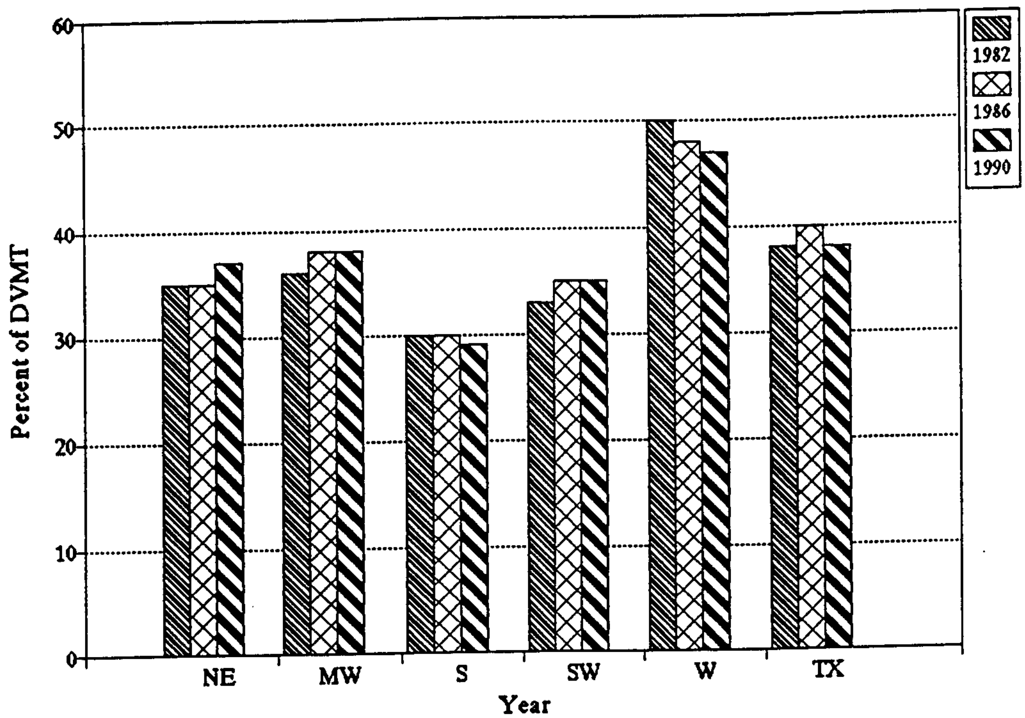

Figure 3. Freeway Percentage of DVMT

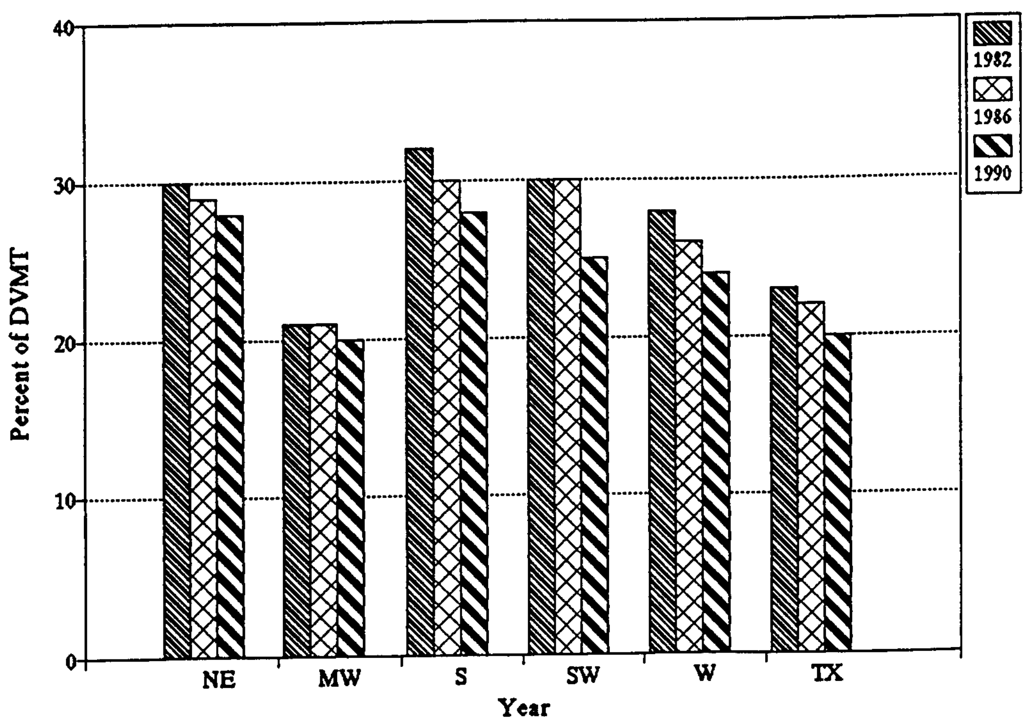

Figure 4. Principal Arterial Street Percentage of DVMT

Additional Capacity

The addition of capacity to alleviate congestion is becoming more difficult in many urban areas, but it can be an effective tool in addressing congestion problems. As Table 8 illustrates, this practice is difficult to maintain over many years. The annual DVMT growth rate is applied to the existing system length to show the amount of additional lane-mileage that is required to prevent congestion levels from increasing. The system capacity has to increase by the same percentage as traffic volume for congestion levels to be maintained.

For example, New York would require 201 additional lane-miles of freeway and 257 lane-miles of principal arterial streets per year to maintain the 1990 congestion level with the 3.4 percent growth in DVMT it experienced between 1987 and 1990.

The amount of additional capacity required for freeway and principal arterial street systems make it apparent that the construction of additional lane-miles as the sole alternative to alleviate congestion is not feasible for many urban areas. Regardless of whether the majority of an area's travel is served by the freeway or principal arterial street system, roadway construction must be combined with a range of other improvements and programs to address the needs of severely congested corridors.

Travel Delays

Travel delay is the most apparent impact of congestion to the motoring public. Analyses of delay have generally been divided into two estimates -- recurring and incident. Recurring delay occurs due to normal daily operations. The most common example of recurring delay is the increased travel time during peak periods of operation.

The other type of delay related to congestion is incident delay. Incident delay is caused by accidents, breakdowns, or other occurrences which decrease roadway capacity. When congestion levels increase (creating higher RCI values), it is the recurring delay that is directly affected. While incident delay is not directly related to or caused by congestion, the delay resulting from incidents significantly increases under congested conditions.

Table 8. Illustration of Annual Capacity Increase
Required to Prevent Congestion Growth

Urban Area	Avg. Annual VMT Growth[1]	Additional Annual Lane-Miles Needed to Maintain 1990 Congestion Level		Average Annual Lane-Miles Added to System, 1987 to 1990	
		Freeway	Prin. Arter.	Freeway	Prin. Arter.
Los Angeles CA	3.8	197	468	117	208
New York NY	3.4	201	257	37	220
Chicago IL	6.3	152	261	80	140
Phoenix AZ	6.3	39	196	95	185
San Diego CA	5.7	99	98	28	50
St. Louis MO	5.3	89	95	88	18
Miami FL	6.1	37	126	17	25
Cleveland OH	6.8	75	76	47	7
San Bernardino-Riv CA	4.4	39	94	13	140
San Fran-Oak CA	2.7	64	62	28	95
Baltimore MD	4.1	51	68	3	0
Minn-St. Paul MN	4.0	60	48	30	13
Washington DC	2.8	43	65	18	20
Pittsburgh PA	3.8	38	69	22	40
Houston TX	2.5	47	53	93	53
Cincinnati OH	5.4	49	44	20	10
Denver CO	3.2	29	60	10	7
Seattle-Everett WA	3.2	38	50	23	33
Detroit MI	1.6	28	59	30	50
Sacramento CA	4.6	35	51	30	33
Philadelphia PA	1.8	27	58	58	10
Salt Lake City UT	9.2	47	33	13	3
San Jose CA	2.5	29	35	7	12
Dallas TX	1.8	31	31	17	7
Atlanta GA	1.8	30	28	23	58
Ft. Lauderdale FL	3.3	20	37	13	15
Kansas City MO	2.2	30	23	10	7
Columbus OH	3.7	29	22	8	5
Orlando FL	2.4	14	37	15	13
Nashville TN	3.6	17	33	20	12
Portland OR	4.1	23	24	5	18
Memphis TN	3.8	15	31	3	18
Milwaukee WI	2.9	17	29	15	8
Jacksonville FL	2.7	12	32	17	20
San Antonio TX	2.2	18	24	3	13
Hartford CT	3.2	19	21	10	17
Charlotte NC	4.3	13	23	7	8
Tampa FL	3.6	11	24	7	17
Albuquerque NM	3.6	8	26	5	23
Fort Worth TX	1.8	18	16	10	3
Louisville KY	3.1	18	16	27	5
Oklahoma City OK	2.4	17	16	7	8
Norfolk VA	2.5	11	18	5	12
El Paso TX	1.8	6	15	0	10
New Orleans LA	1.4	5	9	10	2
Honolulu HI	2.3	8	5	3	3
Indianapolis IN	0.8	6	7	17	12
Boston MA	0.3	4	8	10	27
Austin TX	1.0	5	4	10	5
Corpus Christi TX	0.8	1	3	2	2

[1] Average Annual Growth Rate of Freeway and Principal Arterial Streets traffic volume between 1987 and 1990.

Source: TTI Analysis

Tables 9 and 10 categorize delay by the severity level (moderate, heavy, and severe) for freeways and principal arterial street systems. The congestion categories are based on average daily traffic volumes per lane (9). Table 11 summarizes the vehicle-hours of delay by type and urban area. These values were also used to estimate the economic impacts of congestion.

The rankings in Table 11 are similar to the rankings by RCI (Table 5). Vehicle-hours of delay are also ranked after being normalized by population. The total delay per 1000 persons quantifies the congestion levels independent of urban area size and population. Ranking delay in this manner allows an evaluation similar to the RCI in that it analyzes the effects on individual motorists. Summary statistics show that the Western and Northeastern regions have the largest average per capita delay, while the midwestern region has the least.

Table 9. Freeway and Expressway Recurring and Incident Hours of Daily Delay for 1990[1]

Urban Area	Recurring Hours of Delay				Incident Hours of Delay			
	Moderate	Heavy	Severe	Total	Moderate	Heavy	Severe	Total
Northeastern Cities								
Baltimore MD	3,880	7,320	13,970	25,170	8,930	16,830	32,140	57,900
Boston MA	9,650	20,460	31,260	61,370	33,780	71,620	109,410	214,810
Hartford CT	3,040	1,070	440	4,550	8,210	2,900	1,180	12,290
New York NY	101,900	51,840	133,770	287,510	254,750	129,600	334,430	718,780
Philadelphia PA	9,760	6,360	9,720	25,840	20,490	13,370	20,420	54,280
Pittsburgh PA	1,420	3,020	6,150	10,590	4,130	8,750	17,820	30,700
Washington DC	12,730	30,460	64,290	107,480	28,020	67,010	141,430	236,460
Midwestern Cities								
Chicago IL	11,040	26,020	106,000	143,060	13,250	31,220	127,200	171,670
Cincinnati OH	8,890	5,590	3,410	17,890	7,120	4,470	2,720	14,310
Cleveland OH	8,920	6,730	2,060	17,710	6,250	4,710	1,440	12,400
Columbus OH	730	5,120	8,140	13,990	510	3,590	5,700	9,800
Detroit MI	9,830	6,490	43,020	59,340	21,630	14,270	94,650	130,550
Indianapolis IN	2,690	0	1,390	4,080	4,030	0	2,090	6,120
Kansas City MO	1,510	1,710	0	3,220	4,690	5,310	0	10,000
Louisville KY	760	50	940	1,750	840	60	1,040	1,940
Milwaukee WI	2,780	4,720	6,730	14,230	2,780	4,720	6,730	14,230
Minn-St. Paul MN	5,590	6,780	22,080	34,450	5,030	6,100	19,870	31,000
Oklahoma City OK	1,970	1,470	0	3,440	2,170	1,620	0	3,790
St. Louis MO	8,300	2,350	11,470	22,120	9,960	2,820	13,770	26,550
Southern Cities								
Atlanta GA	4,310	22,330	47,150	73,790	4,740	24,560	51,860	81,160
Charlotte NC	3,790	990	0	4,780	3,030	790	0	3,820
Ft. Lauderdale FL	4,630	3,490	1,070	9,190	6,940	5,230	1,600	13,770
Jacksonville FL	6,330	2,610	0	8,940	9,500	3,910	0	13,410
Memphis TN	1,640	350	0	1,990	1,800	380	0	2,180
Miami FL	6,870	4,450	21,260	32,580	10,310	6,670	31,890	48,870
Nashville TN	3,800	1,530	940	6,270	4,180	1,690	1,030	6,900
New Orleans LA	840	9,050	6,110	16,000	1,520	16,300	11,010	28,830
Norfolk VA	820	5,500	10,260	16,580	2,050	13,750	25,650	41,450
Orlando FL	6,690	2,360	3,410	12,460	10,030	3,540	5,120	18,690
Tampa FL	700	1,860	3,330	5,890	1,050	2,780	5,000	8,830
Southwestern Cities								
Albuquerque NM	580	1,380	920	2,880	630	1,520	1,010	3,160
Austin TX	4,240	6,680	6,930	17,850	4,660	7,350	7,630	19,640
Corpus Christi TX	680	0	0	680	750	0	0	750
Dallas TX	12,670	23,420	47,160	83,250	22,810	42,160	84,890	149,860
Denver CO	5,480	9,290	21,450	36,220	5,480	9,290	21,450	36,220
El Paso TX	1,450	1,770	330	3,550	1,590	1,950	370	3,910
Fort Worth TX	4,610	8,520	17,150	30,280	8,300	15,330	30,870	54,500
Houston TX	7,350	36,380	91,040	134,770	10,290	50,930	127,460	188,680
Phoenix AZ	2,420	14,980	12,030	29,430	970	5,990	4,810	11,770
Salt Lake City UT	1,560	2,090	750	4,400	940	1,250	450	2,640
San Antonio TX	2,360	10,000	11,540	23,900	2,590	11,000	12,700	26,290
Western Cities								
Honolulu HI	2,270	3,750	8,830	14,850	4,090	6,740	15,890	26,720
Los Angeles CA	19,330	21,840	560,610	601,780	23,200	26,200	672,730	722,130
Portland OR	5,970	4,100	7,080	17,150	11,950	8,200	14,150	34,300
Sacramento CA	9,190	9,340	3,970	22,500	5,510	5,600	2,380	13,490
San Bernardino-Riv CA	9,500	8,950	60,140	78,590	11,400	10,740	72,170	94,310
San Diego CA	15,570	18,860	43,530	77,960	9,340	11,310	26,120	46,770
San Fran-Oak CA	25,220	21,390	185,850	232,460	32,790	27,810	241,610	302,210
San Jose CA	9,320	12,240	51,780	73,340	11,190	14,690	62,130	88,010
Seattle-Everett WA	9,010	44,060	29,920	82,990	12,610	61,690	41,890	116,190
Northeastern Avg	20,340	17,220	37,090	74,650	51,190	44,300	93,830	189,320
Midwestern Avg	5,250	5,590	17,100	27,940	6,520	6,570	22,930	36,020
Southern Avg	3,670	4,960	8,500	17,130	5,010	7,240	12,100	24,350
Southwestern Avg	3,940	10,410	19,030	33,380	5,360	13,340	26,510	45,210
Western Avg	11,710	16,060	105,740	133,510	13,560	19,220	127,670	160,450
Texas Avg	4,760	12,400	24,880	42,040	7,280	18,390	37,700	63,370
Total Avg	7,890	10,020	34,390	52,300	13,460	15,770	50,120	79,350
Maximum Value	101,900	51,840	560,610	714,350	254,750	129,600	672,730	1057080
Minimum Value	580	0	0	580	510	0	0	510

Note: [1] Delay calculated based on vehicular speed in Table 13.

Source: TTI Analysis

Table 10. Principal Arterial Street Recurring and Incident Hours of Daily Delay for 1990[1]

Urban Area	Recurring Hours of Delay				Incident Hours of Delay			
	Moderate	Heavy	Severe	Total	Moderate	Heavy	Severe	Total
Northeastern Cities								
Baltimore MD	1,400	2,240	17,280	20,920	1,540	2,470	19,010	23,020
Boston MA	3,090	4,240	21,660	28,990	3,400	4,670	23,830	31,900
Hartford CT	1,470	2,360	2,660	6,490	1,620	2,590	2,920	7,130
New York NY	24,070	45,730	169,480	239,280	26,470	50,300	186,430	263,200
Philadelphia PA	8,940	15,400	68,870	93,210	9,830	16,940	75,760	102,530
Pittsburgh PA	4,950	4,950	27,120	37,020	5,450	5,450	29,830	40,730
Washington DC	3,790	26,160	69,590	99,540	4,170	28,780	76,550	109,500
Midwestern Cities								
Chicago IL	14,980	27,740	59,210	101,930	16,470	30,510	65,130	112,110
Cincinnati OH	1,180	590	2,920	4,690	1,300	650	3,220	5,170
Cleveland OH	1,950	2,980	3,710	8,640	2,140	3,280	4,080	9,500
Columbus OH	850	2,450	4,620	7,920	940	2,700	5,080	8,720
Detroit MI	6,080	13,790	61,380	81,250	6,690	15,170	67,520	89,380
Indianapolis IN	1,680	210	1,540	3,430	1,850	240	1,700	3,790
Kansas City MO	650	820	5,640	7,110	720	900	6,200	7,820
Louisville KY	1,340	4,430	2,280	8,050	1,480	4,880	2,510	8,870
Milwaukee WI	1,830	2,270	4,450	8,550	2,010	2,500	4,890	9,400
Minn-St. Paul MN	2,520	1,210	13,960	17,690	2,780	1,330	15,360	19,470
Oklahoma City OK	1,010	2,020	3,680	6,710	1,110	2,220	4,050	7,380
St. Louis MO	5,260	19,640	15,550	40,450	5,790	21,610	17,110	44,510
Southern Cities								
Atlanta GA	2,650	7,220	27,690	37,560	2,920	7,940	30,460	41,320
Charlotte NC	280	3,440	8,380	12,100	310	3,780	9,220	13,310
Ft. Lauderdale FL	1,870	8,060	12,830	22,760	2,050	8,870	14,110	25,030
Jacksonville FL	2,020	4,440	9,470	15,930	2,220	4,880	10,420	17,520
Memphis TN	1,030	3,300	3,480	7,810	1,140	3,630	3,830	8,600
Miami FL	1,160	6,180	63,730	71,070	1,280	6,800	70,100	78,180
Nashville TN	700	2,490	9,890	13,080	770	2,740	10,880	14,390
New Orleans LA	1,530	2,140	7,770	11,440	1,680	2,350	8,550	12,580
Norfolk VA	1,370	1,880	4,690	7,940	1,500	2,060	5,160	8,720
Orlando FL	520	2,480	16,360	19,360	570	2,720	17,990	21,280
Tampa FL	2,560	1,960	11,110	15,630	2,810	2,160	12,220	17,190
Southwestern Cities								
Albuquerque NM	1,850	3,900	1,230	6,980	2,030	4,290	1,350	7,670
Austin TX	990	1,660	2,070	4,720	1,090	1,830	2,280	5,200
Corpus Christi TX	320	170	110	600	360	180	120	660
Dallas TX	3,710	3,440	4,490	11,640	4,080	3,780	4,940	12,800
Denver CO	3,850	7,850	18,280	29,980	4,240	8,630	20,110	32,980
El Paso TX	130	150	600	880	140	170	660	970
Fort Worth TX	1,890	1,760	2,290	5,940	2,080	1,930	2,520	6,530
Houston TX	3,750	12,430	12,300	28,480	4,120	13,670	13,530	31,320
Phoenix AZ	15,610	21,970	27,360	64,940	17,170	24,170	30,090	71,430
Salt Lake City UT	1,180	1,150	1,500	3,830	1,300	1,260	1,650	4,210
San Antonio TX	840	560	2,790	4,190	930	610	3,070	4,610
Western Cities								
Honolulu HI	1,430	940	3,160	5,530	1,570	1,040	3,480	6,090
Los Angeles CA	28,350	70,580	118,340	217,270	31,190	77,630	130,170	238,990
Portland OR	850	4,950	6,690	12,490	940	5,450	7,360	13,750
Sacramento CA	370	4,720	16,540	21,630	410	5,190	18,190	23,790
San Bernardino-Riv CA	9,800	10,450	10,220	30,470	10,780	11,500	11,250	33,530
San Diego CA	2,400	9,610	1,260	13,270	2,650	10,570	1,390	14,610
San Fran-Oak CA	1,800	6,720	43,810	52,330	1,980	7,390	48,190	57,560
San Jose CA	3,630	2,320	23,480	29,430	3,990	2,560	25,830	32,380
Seattle-Everett WA	2,930	3,910	22,460	29,300	3,230	4,300	24,700	32,230
Northeastern Avg	6,820	14,440	53,810	75,070	7,500	15,880	59,190	82,570
Midwestern Avg	3,280	6,510	14,910	24,700	3,610	7,170	16,400	27,180
Southern Avg	1,430	3,960	15,950	21,340	1,570	4,360	17,540	23,470
Southwestern Avg	3,100	5,000	6,640	14,740	3,410	5,500	7,300	16,210
Western Avg	5,730	12,690	27,330	45,750	6,300	13,960	30,060	50,320
Texas Avg	1,660	2,880	3,520	8,060	1,830	3,170	3,870	8,870
Total Avg	3,770	7,840	21,000	32,610	4,150	8,630	23,100	35,880
Maximum Value	28,350	70,580	169,480	268,410	31,190	77,630	186,430	295,250
Minimum Value	130	150	110	390	140	170	120	430

Note: [1] Delay calculation based on vehicular speed in Table 13.

Source: TTI Analysis

Table 11. Total Vehicle Hours of Delay for 1990

Urban Area	Vehicle Hours of Delay				Total Delay per 1000 Persons	Rank[1]
	Recurring	Incident	Total	Rank[1]		
Northeastern Cities						
Baltimore MD	46,090	80,910	127,010	20	60	31
Boston MA	90,370	246,700	337,070	8	110	11
Hartford CT	11,040	19,430	30,470	41	50	35
New York NY	526,790	981,980	1,508,760	2	90	12
Philadelphia PA	119,060	156,810	275,870	9	70	24
Pittsburgh PA	47,610	71,430	119,040	21	60	31
Washington DC	207,030	345,960	552,990	4	180	2
Midwestern Cities						
Chicago IL	244,980	283,790	528,770	5	70	24
Cincinnati OH	22,590	19,480	42,060	37	40	39
Cleveland OH	26,330	21,890	48,220	33	30	42
Columbus OH	21,920	18,510	40,430	39	50	35
Detroit MI	140,600	219,940	360,540	7	90	12
Indianapolis IN	7,520	9,900	17,420	47	20	45
Kansas City MO	10,330	17,820	28,160	42	20	45
Louisville KY	9,810	10,790	20,610	45	30	42
Milwaukee WI	22,780	23,630	46,410	36	40	39
Minn-St. Paul MN	52,150	50,470	102,620	22	50	35
Oklahoma City OK	10,150	11,160	21,310	43	30	42
St. Louis MO	62,580	71,050	133,630	19	70	24
Southern Cities						
Atlanta GA	111,350	122,480	233,830	13	120	9
Charlotte NC	16,880	17,140	34,020	40	80	17
Ft. Lauderdale FL	31,930	38,800	70,740	28	60	31
Jacksonville FL	24,870	30,930	55,790	31	80	17
Memphis TN	9,800	10,780	20,580	46	20	45
Miami FL	103,650	127,050	230,700	14	120	9
Nashville TN	19,350	21,290	40,640	38	70	24
New Orleans LA	27,450	41,410	68,860	29	60	31
Norfolk VA	24,510	50,170	74,680	26	80	17
Orlando FL	31,810	39,980	71,790	27	80	17
Tampa FL	21,520	26,020	47,540	34	70	24
Southwestern Cities						
Albuquerque NM	9,850	10,830	20,680	44	40	39
Austin TX	22,580	24,840	47,410	35	90	12
Corpus Christi TX	1,280	1,410	2,690	50	10	50
Dallas TX	94,900	162,670	257,570	11	130	7
Denver CO	66,200	69,200	135,400	18	90	12
El Paso TX	4,440	4,880	9,320	49	20	45
Fort Worth TX	36,210	61,030	97,240	23	80	17
Houston TX	163,250	220,000	383,250	6	130	7
Phoenix AZ	94,360	83,200	177,570	16	90	12
Salt Lake City UT	8,220	6,850	15,070	48	20	45
San Antonio TX	28,090	30,900	58,990	30	50	35
Western Cities						
Honolulu HI	20,380	32,800	53,180	32	80	17
Los Angeles CA	819,040	961,130	1,780,170	1	160	4
Portland OR	29,650	48,050	77,700	25	80	17
Sacramento CA	44,120	37,280	81,400	24	70	24
San Bernardino-Riv CA	109,060	127,820	236,880	12	200	1
San Diego CA	91,230	61,370	152,600	17	70	24
San Fran-Oak CA	284,800	359,770	644,570	3	180	2
San Jose CA	102,780	120,390	223,170	15	160	4
Seattle-Everett WA	112,290	148,420	260,710	10	150	6
Northeastern Avg	149,710	271,890	421,600		90	
Midwestern Avg	52,650	63,200	115,850		40	
Southern Avg	38,470	47,820	86,290		80	
Southwestern Avg	48,130	61,440	109,560		70	
Western Avg	179,260	210,780	390,040		130	
Texas Avg	50,110	72,250	122,350		70	
Total Avg	84,910	115,210	200,120		80	
Maximum Value	819,040	981,980	1,780,170		200	
Minimum Value	1,280	1,410	2,690		10	

Note: [1] Rank value of 1 associated with most congested conditions

Source: TTI Analysis

COST OF CONGESTION

Another method of assessing impact is to look at economic factors. Two quantities closely related to congestion are delay and wasted fuel. This chapter presents estimates of the value of traffic delay and fuel wasted due to congested traffic for the 50 study areas.

Economic Impact Estimates

Estimates of congestion costs were based on the congested peak-period VMT on freeways and principal arterial street systems. Table 12 lists the freeway and principal arterial street DVMT and populations utilized in the congestion cost estimates. The data shown in this table were obtained through the HPMS database and various state and local agencies.

The two primary components of the congestion cost estimates were traffic delay and excess fuel consumption. Congestion severity affects both the travel time and fuel consumption by decreasing the speed and vehicle fuel efficiency as congestion becomes worse. The congestion categories used to estimate vehicle-hours of delay (Table 11) were also used to estimate fuel consumption. The vehicular speeds used in the congestion cost estimates are shown in Table 13.

Congestion cost estimates also used several study constants and urban area variables in the calculations. The five values held constant for all urban areas in the congestion cost analyses and calculations included:

1. Average vehicle occupancy -- 1.25 persons per vehicle
2. Working days per year -- 250 days
3. Average cost of time (9) -- $10.00 per person-hour (1990 value)
4. Commercial vehicle operating cost (10) -- $1.95 per mile (1990 value)
5. Vehicle mix -- 95 percent passenger and 5 percent commercial

Table 12. Summary of 1990 DVMT Values and Population for Congestion Cost Estimates

Urban Area	Daily Vehicle-Miles of Travel (1000) Freeway/ Expressway	Principal Arterial Street	Freeway and Arterial	Population (1000)
Northeastern Cities				
Baltimore MD	15,800	9,850	25,650	1,990
Boston MA	21,610	12,540	34,150	2,960
Hartford CT	6,230	3,750	9,980	610
New York NY	82,920	52,060	134,980	16,780
Philadelphia PA	18,330	21,390	39,720	4,220
Pittsburgh PA	8,200	10,910	19,110	1,870
Washington DC	25,340	19,560	44,900	3,100
Midwestern Cities				
Chicago IL	38,030	29,050	67,080	7,510
Cincinnati OH	11,380	3,670	15,050	1,140
Cleveland OH	13,700	5,790	19,490	1,790
Columbus OH	8,350	3,180	11,530	850
Detroit MI	22,650	22,880	45,520	4,000
Indianapolis IN	8,050	3,970	12,020	950
Kansas City MO	12,560	4,810	17,370	1,160
Louisville KY	6,200	2,950	9,140	810
Milwaukee WI	7,690	4,780	12,470	1,230
Minn-St. Paul MN	17,790	5,640	23,430	2,010
Oklahoma City OK	6,940	3,590	10,520	740
St. Louis MO	19,120	12,960	32,080	1,960
Southern Cities				
Atlanta GA	24,260	9,780	34,040	1,880
Charlotte NC	2,300	3,090	5,390	450
Ft. Lauderdale FL	7,110	5,800	12,910	1,270
Jacksonville FL	5,380	5,810	11,190	720
Memphis TN	4,340	4,240	8,580	860
Miami FL	8,570	15,810	24,380	1,850
Nashville TN	5,000	5,440	10,440	570
New Orleans LA	4,970	4,100	9,070	1,080
Norfolk VA	5,450	4,260	9,710	930
Orlando FL	5,950	3,850	9,800	850
Tampa FL	3,630	4,360	7,990	700
Southwestern Cities				
Albuquerque NM	2,400	3,790	6,190	530
Austin TX	5,440	2,090	7,530	510
Corpus Christi TX	1,560	1,500	3,060	280
Dallas TX	23,680	8,310	31,990	1,990
Denver CO	11,270	10,900	22,170	1,580
El Paso TX	3,330	3,200	6,530	540
Fort Worth TX	11,840	4,240	16,080	1,200
Houston TX	28,230	10,830	39,060	2,880
Phoenix AZ	7,670	17,610	25,280	1,900
Salt Lake City UT	5,330	2,040	7,370	800
San Antonio TX	9,280	5,240	14,520	1,170
Western Cities				
Honolulu HI	4,620	1,570	6,190	660
Los Angeles CA	110,350	80,370	190,720	11,420
Portland OR	7,470	3,710	11,180	1,030
Sacramento CA	9,260	7,000	16,260	1,100
San Bernardino-Riv CA	14,580	10,150	24,730	1,170
San Diego CA	27,690	9,340	37,030	2,300
San Fran-Oak CA	42,590	14,000	56,590	3,680
San Jose CA	15,780	6,780	22,560	1,410
Seattle-Everett WA	18,920	9,130	28,050	1,730
Northeastern Avg	25,490	18,580	44,070	4,500
Midwestern Avg	14,370	8,600	22,970	2,010
Southern Avg	7,000	6,050	13,040	1,010
Southwestern Avg	10,000	6,340	16,340	1,220
Western Avg	27,920	15,780	43,700	2,720
Texas Avg	11,910	5,060	16,970	1,220
Total Avg	15,780	10,230	26,010	2,090
Maximum Value	110,350	80,370	190,720	16,780
Minimum Value	1,560	1,500	3,060	280

Source: TTI Analysis and Local Transportation Agency References

Table 13. Speed Relationships with Average Daily Traffic per Lane Volumes

Functional Class	Parameters	Severity of Congestion[1,2]		
		Moderate	Heavy	Severe
Freeway/Expressway	ADT/Lane	15,000 - 17,500	17,501 - 20,000	Over 20,000
	Speed (mph)[3]	38	33	30
Principal Arterial Streets	ADT/Lane	5,750 - 7,000	7,001 - 8,500	Over 8,500
	Speed (mph)[3]	28	25	23

Note: [1]Assumes congested freeway operation when ADT/Lane exceeds 15,000.
[2]Assumes congested principal arterial street operations when ADT/lane exceeds 5,750.
[3]Value represents a weighted average

Source: TTI Analysis and Houston-Galveston Regional Transportation Study

Four area specific variables were also used in the congestion cost estimates. These variables are briefly described below:

1. Daily vehicle-miles of travel (DVMT) -- the average daily traffic (ADT) of a section of roadway multiplied by the length (in miles) of that roadway section.

2. Fuel cost -- the state average fuel cost per gallon for 1990.

3. Registered vehicles -- the number of registered vehicles as reported by local agencies.

4. Population -- estimated using the 1990 Census Bureau estimates and HPMS data.

These variables were used to estimate and analyze the effects of congestion in each urban area. The economic impact of congestion was stated in terms of annual congestion cost, cost per registered vehicle, and cost per capita. Previous reports have included additional insurance costs resulting from operating a vehicle in larger metropolitan areas. Due to the difficulty in obtaining data from the insurance industry, these costs were omitted from this cost analysis.

Economic Analysis

While the above variables are used to analyze congestion cost in this study, it should be recognized that some of these cost variables fluctuate with economic trends. The variables -- fuel cost, commercial vehicle operating cost, and the average cost of time -- are updated annually to reflect the change in these costs. Estimates of vehicle-hours of delay and gallons of wasted fuel should be used to analyze congestion trends.

Table 14 gives the total delay in each urban area from 1986 to 1990. Thirty-four of the 50 urban areas had at least a 15 percent growth in delay over the five-year period. Ten of the areas had at least a 50 percent growth in the same period. Sacramento showed a 100 percent increase in delay during this same time. Only two urban areas (Austin and San Antonio) displayed a decrease in delay over this five-year period.

The summary statistics show that only the Midwestern and Texas regions did not have at least a 15 percent growth in delay from 1986 to 1990. The Texas region had no change in delay over this period. The Northeastern and Southern regions showed the largest percent increase in total delay over the five-year period.

As congestion increases, slower vehicle speeds result in increased fuel consumption. The procedure used to estimate the amount of wasted fuel is tied to the average speed values used to calculate vehicle delay. The change in wasted fuel and vehicle delay are, thus, closely related. While this is not appropriate over all speed ranges, it provides reasonable estimates of areawide fuel consumption. The equation used to estimate fuel consumption has a linear relationship to speed.

The amount of fuel which was wasted due to congestion from 1986 to 1990 is shown in Table 15. The summary statistics show that the Northeastern and Southern regions had the highest average growth over the period. The Southwestern and Texas regions were the only two which did not surpass a 15 percent growth in wasted fuel over the five year period.

The component and total congestion costs for each urban area are shown in Table 16. In 1990, the total cost of congestion for the urban areas studied was approximately $43.2 billion. This represents a 10 percent increase in the economic impact of congestion since 1989 ($39.2 billion). The increase in the value of time rate was 8 percent and fuel costs averaged a 9 percent increase. Studywide averages indicate that recurring and incident delay accounted for

Table 14. Total Vehicle Delay, 1986 to 1990

Urban Area	Total Delay (1000 Veh-Hours) 1986	1987	1988	1989	1990	% change 1986-1990
Northeastern Cities						
Baltimore MD	95	100	105	120	125	32
Boston MA	285	270	370	350	335	18
Hartford CT	20	20	30	35	30	50
New York NY	1,190	1,265	1,370	1,515	1,510	27
Philadelphia PA	250	270	275	270	275	10
Pittsburgh PA	95	100	115	115	120	26
Washington DC	440	475	495	540	555	26
Midwestern Cities						
Chicago IL	480	470	470	495	530	10
Cincinnati OH	25	30	40	40	40	60
Cleveland OH	35	40	45	45	50	43
Columbus OH	30	35	35	40	40	33
Detroit MI	340	345	350	360	360	6
Indianapolis IN	10	10	15	15	15	50
Kansas City MO	20	20	25	25	30	50
Louisville KY	20	20	20	20	20	0
Milwaukee WI	35	40	45	45	45	29
Minn-St. Paul MN	70	95	95	95	105	50
Oklahoma City OK	20	20	25	20	20	0
St. Louis MO	115	120	105	140	135	17
Southern Cities						
Atlanta GA	225	240	225	230	235	4
Charlotte NC	25	25	30	30	35	40
Ft. Lauderdale FL	65	65	70	65	70	8
Jacksonville FL	40	45	45	55	55	38
Memphis TN	15	15	20	20	20	33
Miami FL	150	170	200	220	230	53
Nashville TN	30	35	40	40	40	33
New Orleans LA	65	65	70	70	70	8
Norfolk VA	60	70	70	75	75	25
Orlando FL	60	60	60	70	70	17
Tampa FL	35	40	45	45	50	43
Southwestern Cities						
Albuquerque NM	15	15	15	20	20	33
Austin TX	50	45	45	45	45	-10
Corpus Christi TX	5	5	5	5	5	0
Dallas TX	260	235	240	240	260	0
Denver CO	110	110	115	120	135	23
El Paso TX	10	10	10	10	10	0
Fort Worth TX	95	90	90	90	95	0
Houston TX	370	355	365	375	385	4
Phoenix AZ	145	145	185	180	180	24
Salt Lake City UT	10	15	15	15	15	50
San Antonio TX	65	65	60	60	60	-8
Western Cities						
Honolulu HI	45	45	50	55	55	22
Los Angeles CA	1,645	1,715	1,685	1,750	1,780	8
Portland OR	50	60	70	75	80	60
Sacramento CA	40	55	70	80	80	100
San Bernardino-Riv CA	185	190	215	230	235	27
San Diego CA	95	125	145	155	155	63
San Fran-Oak CA	540	615	625	650	645	19
San Jose CA	195	210	215	225	225	15
Seattle-Everett WA	175	210	235	255	260	49
Northeastern Avg	340	360	395	420	420	24
Midwestern Avg	100	105	105	110	115	15
Southern Avg	70	75	80	85	85	21
Southwestern Avg	100	100	105	105	110	10
Western Avg	330	360	370	385	390	18
Texas Avg	120	115	115	120	120	0
Total Avg	170	180	185	195	200	18
Maximum Value	1,645	1,715	1,685	1,750	1,780	
Minimum Value	5	5	5	5	5	

Source: TTI Analysis

Table 15. Annual Wasted Fuel Due to Congestion

Urban Area	Annual Wasted Gallons (millions)					% change 1986-1990
	1986	1987	1988	1989	1990	
Northeastern Cities						
Baltimore MD	44	46	48	53	57	30
Boston MA	132	125	168	160	155	17
Hartford CT	9	10	14	15	14	56
New York NY	547	577	622	689	691	26
Philadelphia PA	107	115	118	117	119	11
Pittsburgh PA	41	44	48	49	51	24
Washington DC	199	214	221	240	243	22
Midwestern Cities						
Chicago IL	212	208	204	221	236	11
Cincinnati OH	12	15	18	19	20	67
Cleveland OH	16	18	21	22	24	50
Columbus OH	14	16	17	18	19	36
Detroit MI	150	151	153	157	158	5
Indianapolis IN	5	5	7	7	8	60
Kansas City MO	10	10	12	12	13	30
Louisville KY	8	9	9	9	9	13
Milwaukee WI	17	19	20	20	21	24
Minn-St. Paul MN	33	42	43	44	47	42
Oklahoma City OK	9	8	10	10	10	11
St. Louis MO	51	53	47	61	55	8
Southern Cities						
Atlanta GA	97	105	101	104	105	8
Charlotte NC	11	11	14	15	16	45
Ft. Lauderdale FL	30	32	33	31	33	10
Jacksonville FL	18	21	20	24	25	39
Memphis TN	7	7	8	9	9	29
Miami FL	67	73	89	95	99	48
Nashville TN	13	15	18	18	18	38
New Orleans LA	29	29	31	31	31	7
Norfolk VA	28	32	32	33	34	21
Orlando FL	29	28	28	31	32	10
Tampa FL	16	17	19	19	20	25
Southwestern Cities						
Albuquerque NM	6	7	8	9	9	50
Austin TX	23	21	20	21	24	4
Corpus Christi TX	1	1	1	1	1	0
Dallas TX	120	112	115	115	122	2
Denver CO	49	49	52	55	64	31
El Paso TX	5	4	4	4	5	0
Fort Worth TX	43	42	43	43	46	7
Houston TX	170	164	169	173	177	4
Phoenix AZ	63	63	79	78	78	24
Salt Lake City UT	5	6	6	7	7	40
San Antonio TX	29	29	28	28	28	-3
Western Cities						
Honolulu HI	21	21	24	24	25	19
Los Angeles CA	743	774	754	784	799	8
Portland OR	23	28	32	35	36	57
Sacramento CA	20	25	32	36	37	85
San Bernardino-Riv CA	72	80	98	104	109	51
San Diego CA	46	60	68	72	70	52
San Fran-Oak CA	246	280	287	297	297	21
San Jose CA	84	90	99	102	102	21
Seattle-Everett WA	81	98	109	118	121	49
Northeastern Avg	154	162	177	189	190	23
Midwestern Avg	45	46	47	50	52	16
Southern Avg	31	34	36	37	39	26
Southwestern Avg	47	45	48	48	51	9
Western Avg	149	162	167	175	177	19
Texas Avg	56	53	54	55	57	2
Total Avg	76	80	84	89	91	20
Maximum Value	743	774	754	784	799	1345
Minimum Value	1	1	1	1	1	

Source: TTI Analysis

Table 16. **Component and Total Congestion Costs By Urban Area for 1990**

Urban Area	Annual Cost Due to Congestion ($Millions) Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total Cost	Rank
Los Angeles CA	3,000	3,530	530	620	7,670	1
New York NY	1,950	3,630	350	640	6,560	2
San Fran-Oak CA	1,050	1,330	190	240	2,810	3
Washington DC	760	1,260	130	220	2,370	4
Chicago IL	900	1,040	160	190	2,280	5
Houston TX	600	810	100	140	1,650	6
Detroit MI	510	800	80	130	1,530	7
Boston MA	330	910	60	160	1,460	8
Philadelphia PA	430	570	70	90	1,160	9
Seattle-Everett WA	420	550	70	100	1,140	10
Dallas TX	350	610	60	100	1,120	11
San Bernardino-Riv CA	400	470	70	80	1,030	12
Atlanta GA	410	450	60	70	1,000	13
Miami FL	370	460	60	70	970	15
San Jose CA	380	440	70	80	970	15
Phoenix AZ	340	300	60	50	750	16
San Diego CA	340	230	60	40	670	17
Denver CO	240	250	40	40	580	18
St. Louis MO	230	260	30	40	560	19
Baltimore MD	170	300	30	50	550	20
Pittsburgh PA	170	260	30	40	500	21
Minn-St. Paul MN	190	190	30	30	440	22
Fort Worth TX	140	230	20	40	420	23
Sacramento CA	160	140	30	20	350	24
Portland OR	110	180	20	30	340	25
Norfolk VA	90	180	20	30	320	26
Orlando FL	120	150	20	20	310	27
Ft. Lauderdale FL	120	140	20	20	300	29
New Orleans LA	100	150	20	30	300	29
San Antonio TX	100	120	20	20	260	30
Honolulu HI	80	120	20	30	240	32
Jacksonville FL	90	110	20	20	240	32
Austin TX	80	90	10	20	210	34
Cleveland OH	100	80	20	10	210	34
Milwaukee WI	80	90	10	10	200	36
Tampa FL	80	90	10	20	200	36
Cincinnati OH	90	70	20	10	190	37
Columbus OH	80	70	10	10	170	39
Nashville TN	70	80	10	10	170	39
Charlotte NC	60	60	10	10	150	40
Hartford CT	40	70	10	10	130	41
Kansas City MO	40	70	10	10	120	42
Albuquerque NM	40	40	10	10	90	45
Louisville KY	40	40	10	10	90	45
Memphis TN	40	40	10	10	90	45
Oklahoma City OK	40	40	10	10	90	45
Indianapolis IN	30	40	0	10	80	47
Salt Lake City UT	30	30	10	0	70	48
El Paso TX	20	20	0	0	40	49
Corpus Christi TX	0	10	0	0	10	50
Northeastern Avg	550	1,000	100	170	1,820	
Midwestern Avg	190	230	30	40	500	
Southern Avg	140	170	20	30	370	
Southwestern Avg	180	230	30	40	470	
Western Avg	660	780	120	140	1,690	
Texas Avg	190	270	30	40	530	
Total Avg	310	420	50	70	860	
Maximum Value	3,000	3,630	530	640	7,670	
Minimum Value	0	10	0	0	10	

Source: TTI Analysis and Local Transportation Agency References

approximately 85 percent of an urban area's congestion cost. The average economic burden placed on urban areas in 1990 due to congestion was $860 million, compared to $780 million in 1989.

Thirteen urban areas had total congestion costs equal to or exceeding $1 billion. Of the seven urban areas studied in Texas only two, Houston -- 6th and Dallas -- 11th, ranked in the top fifteen. Congestion in the Texas urbanized areas resulted in a cost of approximately $3.7 billion, a 12 percent increase from 1989 congestion costs.

Table 17 illustrates the estimated economic impact of congestion per capita and per registered vehicle. Viewing congestion costs in relation to population and vehicles provides an estimate of the effects of congestion on the individual. The urban area with the highest per vehicle cost was Washington, D.C. ($1,420 per registered vehicle), while San Bernardino-Riverside had the highest per capita cost ($880 per person). The relationships of these cost estimates to total congestion cost can be seen in Table 18, which illustrates the rankings of urban areas by the annual, per capita, and per registered vehicle costs. The rankings of the cost estimates are fairly consistent with 15 urban areas occupying the top ten positions in all three categories. The 1989 and 1990 rankings of the RCI values and the congestion costs per capita are displayed in Table 19. The change during the past year can be seen in the costs and RCI rankings.

Tables 20 through 27 present estimates of congestion cost from 1986 to 1989. Previously published estimates presented in this series of reports have been revised for some areas to reflect new information. The data in Tables 20 through 27 are the best current information on the delay, fuel and cost values for the years 1986 through 1989. Some of the data missing in 1986 and 1987 was unobtainable because of the various methods of reporting information in the HPMS database.

Table 17. Estimated Unit Costs of Congestion in 1990

Urban Area	Total Congestion Cost: Per Registered Vehicle (Dollars)	Total Congestion Cost: Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	530	270
Boston MA	880	490
Hartford CT	250	220
New York NY	1,090	390
Philadelphia PA	420	270
Pittsburgh PA	400	270
Washington DC	1,420	770
Midwestern Cities		
Chicago IL	570	300
Cincinnati OH	200	160
Cleveland OH	140	120
Columbus OH	230	200
Detroit MI	530	380
Indianapolis IN	130	80
Kansas City MO	160	100
Louisville KY	190	110
Milwaukee WI	370	160
Minn-St. Paul MN	270	220
Oklahoma City OK	190	120
St. Louis MO	540	290
Southern Cities		
Atlanta GA	640	530
Charlotte NC	390	320
Ft. Lauderdale FL	290	240
Jacksonville FL	400	330
Memphis TN	140	100
Miami FL	680	520
Nashville TN	340	310
New Orleans LA	340	270
Norfolk VA	390	350
Orlando FL	420	360
Tampa FL	310	290
Southwestern Cities		
Albuquerque NM	210	170
Austin TX	410	410
Corpus Christi TX	50	40
Dallas TX	750	570
Denver CO	420	370
El Paso TX	120	80
Fort Worth TX	420	350
Houston TX	750	570
Phoenix AZ	630	400
Salt Lake City UT	90	80
San Antonio TX	290	220
Western Cities		
Honolulu HI	470	360
Los Angeles CA	980	670
Portland OR	500	330
Sacramento CA	280	320
San Bernardino-Riv CA	1,320	880
San Diego CA	480	290
San Fran-Oak CA	930	760
San Jose CA	960	690
Seattle-Everett WA	880	660
Northeastern Avg	710	380
Midwestern Avg	290	190
Southern Avg	390	330
Southwestern Avg	380	300
Western Avg	760	550
Texas Avg	400	320
Total Avg	480	340
Maximum Value	1,420	880
Minimum Value	50	40

Source: TTI Analysis and Local Transportation Agency References

Table 18. 1990 Rankings of Urban Area by Estimated Impact of Congestion

Urban Area	Areawide Cost of Congestion	Congestion Cost per Capita	Congestion Cost per Reg. Vehicle
Northeastern Cities			
Baltimore MD	20	30	17
Boston MA	8	11	8
Hartford CT	41	37	38
New York NY	2	14	3
Philadelphia PA	9	31	24
Pittsburgh PA	21	33	26
Washington DC	4	2	1
Midwestern Cities			
Chicago IL	5	26	14
Cincinnati OH	37	40	41
Cleveland OH	33	43	45
Columbus OH	38	38	39
Detroit MI	7	15	16
Indianapolis IN	47	48	47
Kansas City MO	42	45	44
Louisville KY	46	44	42
Milwaukee WI	35	41	30
Minn-St. Paul MN	22	35	37
Oklahoma City OK	43	42	43
St. Louis MO	19	28	15
Southern Cities			
Atlanta GA	13	9	12
Charlotte NC	40	24	29
Ft. Lauderdale FL	28	34	35
Jacksonville FL	31	21	27
Memphis TN	45	46	46
Miami FL	15	10	11
Nashville TN	39	25	32
New Orleans LA	29	32	31
Norfolk VA	26	20	28
Orlando FL	27	17	23
Tampa FL	36	29	33
Southwestern Cities			
Albuquerque NM	44	39	40
Austin TX	34	12	25
Corpus Christi TX	50	50	50
Dallas TX	11	8	9
Denver CO	18	16	22
El Paso TX	49	49	48
Fort Worth TX	23	19	21
Houston TX	6	7	10
Phoenix AZ	16	13	13
Salt Lake City UT	48	47	49
San Antonio TX	30	36	34
Western Cities			
Honolulu HI	32	18	20
Los Angeles CA	1	5	4
Portland OR	25	22	18
Sacramento CA	24	23	36
San Bernardino-Riv CA	12	1	2
San Diego CA	17	27	19
San Fran-Oak CA	3	3	6
San Jose CA	14	4	5
Seattle-Everett WA	10	6	7

Source: TTI Analysis

Table 19. 1990 Congestion Index Values

Urban Area	DVMT/Ln-Miles Frwy	DVMT/Ln-Miles Prin. Art Street	Roadway Congestion Index 1990 Value	Roadway Congestion Index Rank 1989	Roadway Congestion Index Rank 1990	Congestion Costs Per Capita[1] 1989	Congestion Costs Per Capita[1] 1990
Northeastern Cities							
Baltimore MD	12,640	5,930	1.01	24	24	250	270
Boston MA	14,220	4,540	1.06	13	16	470	490
Hartford CT	10,730	5,910	0.89	37	37	230	220
New York NY	14,050	6,890	1.14	12	9	370	390
Philadelphia PA	12,140	6,580	1.05	17	17	250	270
Pittsburgh PA	8,200	5,990	0.82	42	44	240	270
Washington DC	16,610	8,500	1.37	2	2	690	770
Midwestern Cities							
Chicago IL	15,680	6,980	1.25	5	5	270	300
Cincinnati OH	12,570	4,480	0.96	30	28	140	160
Cleveland OH	12,450	5,170	0.97	28	27	110	120
Columbus OH	10,440	5,210	0.83	42	42	180	200
Detroit MI	13,320	6,350	1.09	15	14	360	380
Indianapolis IN	10,590	4,510	0.83	41	42	70	80
Kansas City MO	9,230	4,540	0.74	48	47	90	100
Louisville KY	10,500	5,660	0.86	40	40	100	110
Milwaukee WI	12,920	4,760	0.99	25	25	140	160
Minn-St. Paul MN	12,020	4,700	0.93	35	33	200	220
Oklahoma City OK	9,630	5,270	0.79	45	45	120	120
St. Louis MO	11,280	7,200	0.99	26	25	280	290
Southern Cities							
Atlanta GA	14,190	6,230	1.11	9	12	490	530
Charlotte NC	7,670	5,770	0.78	46	46	280	320
Ft. Lauderdale FL	11,840	5,200	0.94	32	30	210	240
Jacksonville FL	11,960	4,840	0.94	31	30	300	330
Memphis TN	11,130	5,230	0.91	33	35	90	100
Miami FL	14,170	7,620	1.26	4	4	470	520
Nashville TN	10,200	5,790	0.89	35	37	290	310
New Orleans LA	13,810	6,560	1.12	10	10	260	270
Norfolk VA	11,720	5,790	0.96	28	28	310	350
Orlando FL	10,080	2,450	0.72	48	49	340	360
Tampa FL	12,100	6,610	1.05	18	17	250	290
Southwestern Cities							
Albuquerque NM	11,160	5,260	0.93	33	33	160	170
Austin TX	12,090	4,860	0.94	26	30	370	410
Corpus Christi TX	8,430	4,620	0.72	50	49	40	40
Dallas TX	13,850	4,860	1.05	20	17	500	570
Denver CO	12,730	5,890	1.03	22	21	310	370
El Paso TX	9,510	3,830	0.74	46	47	70	80
Fort Worth TX	11,610	4,870	0.90	38	36	320	350
Houston TX	14,700	5,080	1.12	10	10	520	570
Phoenix AZ	12,270	5,640	1.03	18	21	370	400
Salt Lake City UT	10,450	5,730	0.85	44	41	80	80
San Antonio TX	11,250	4,810	0.88	38	39	200	220
Western Cities							
Honolulu HI	13,590	7,860	1.11	13	12	330	360
Los Angeles CA	21,100	6,480	1.55	1	1	620	670
Portland OR	13,460	6,400	1.07	16	15	300	330
Sacramento CA	12,350	6,360	1.02	22	23	300	320
San Bernardino-Riv CA	16,290	4,740	1.19	8	8	840	880
San Diego CA	16,050	5,460	1.22	7	6	280	290
San Fran-Oak CA	17,820	6,110	1.35	2	3	720	760
San Jose CA	13,600	4,860	1.04	20	20	650	690
Seattle-Everett WA	15,640	5,800	1.20	5	7	610	660

Notes: [1] Cost includes delay and fuel

Source: TTI Analysis and Local Transportation Agency References

Table 20. Component and Total Congestion Costs By Urban Area for 1986

Urban Area	Annual Cost Due to Congestion ($Millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	-	-	-	-	-
Boston MA	-	-	-	-	-
Hartford CT	20	40	-	-	-
New York NY	-	-	-	-	-
Philadelphia PA	-	-	-	-	-
Pittsburgh PA	-	-	-	-	-
Washington DC	-	-	-	-	-
Midwestern Cities					
Chicago IL	-	-	-	-	-
Cincinnati OH	-	-	-	-	-
Cleveland OH	-	-	-	-	-
Columbus OH	50	40	-	-	-
Detroit MI	-	-	-	-	-
Indianapolis IN	-	-	-	-	-
Kansas City MO	20	40	0	10	70
Louisville KY	30	30	0	0	60
Milwaukee WI	60	60	10	10	130
Minn-St. Paul MN	110	110	20	20	250
Oklahoma City OK	-	-	-	-	-
St. Louis MO	160	180	90	100	540
Southern Cities					
Atlanta GA	330	360	50	50	780
Charlotte NC	40	40	-	-	-
Ft. Lauderdale FL	90	100	10	20	220
Jacksonville FL	50	70	10	10	140
Memphis TN	20	20	0	0	50
Miami FL	210	250	30	40	520
Nashville TN	40	50	10	10	110
New Orleans LA	80	120	10	20	220
Norfolk VA	60	130	-	-	-
Orlando FL	80	100	10	20	210
Tampa FL	50	60	10	10	130
Southwestern Cities					
Albuquerque NM	20	20	0	0	50
Austin TX	70	80	10	10	180
Corpus Christi TX	0	0	0	0	10
Dallas TX	290	500	40	70	910
Denver CO	160	170	20	30	380
El Paso TX	10	20	0	0	30
Fort Worth TX	110	180	20	30	330
Houston TX	480	640	70	90	1,290
Phoenix AZ	230	210	40	30	500
Salt Lake City UT	20	20	0	0	40
San Antonio TX	90	100	10	10	220
Western Cities					
Honolulu HI	50	90	10	10	160
Los Angeles CA	2,300	2,690	360	420	5,760
Portland OR	60	90	10	10	170
Sacramento CA	70	60	10	10	150
San Bernardino-Riv CA	260	300	40	50	650
San Diego CA	180	120	30	20	350
San Fran-Oak CA	730	920	110	140	1,900
San Jose CA	270	320	40	50	690
Seattle-Everett WA	230	300	40	50	620
Northeastern Avg	20	40	-	-	-
Midwestern Avg	70	80	20	30	210
Southern Avg	100	120	20	20	260
Southwestern Avg	140	180	20	30	360
Western Avg	460	540	70	80	1,160
Texas Avg	150	220	20	30	420
Total Avg	190	230	30	40	520
Maximum Value	2,300	2,690	360	420	5,760
Minimum Value	0	0	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 21. Estimated Impact of Congestion in 1986

Urban Area	Total Congestion Cost Per Registered Vehicle (Dollars)	Total Congestion Cost Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	-	-
Boston MA	-	-
Hartford CT	-	-
New York NY	-	-
Philadelphia PA	-	-
Pittsburgh PA	-	-
Washington DC	-	-
Midwestern Cities		
Chicago IL	-	-
Cincinnati OH	-	-
Cleveland OH	-	-
Columbus OH	-	-
Detroit MI	-	-
Indianapolis IN	-	-
Kansas City MO	120	70
Louisville KY	140	80
Milwaukee WI	160	110
Minn-St. Paul MN	220	130
Oklahoma City OK	-	-
St. Louis MO	390	280
Southern Cities		
Atlanta GA	550	460
Charlotte NC	-	-
Ft. Lauderdale FL	230	190
Jacksonville FL	250	210
Memphis TN	110	60
Miami FL	370	290
Nashville TN	300	210
New Orleans LA	270	210
Norfolk VA	-	-
Orlando FL	370	300
Tampa FL	190	210
Southwestern Cities		
Albuquerque NM	130	100
Austin TX	390	380
Corpus Christi TX	40	40
Dallas TX	560	480
Denver CO	300	250
El Paso TX	100	70
Fort Worth TX	360	290
Houston TX	680	460
Phoenix AZ	450	290
Salt Lake City UT	60	50
San Antonio TX	280	230
Western Cities		
Honolulu HI	330	270
Los Angeles CA	750	540
Portland OR	290	170
Sacramento CA	140	160
San Bernardino-Riv CA	960	660
San Diego CA	320	180
San Fran-Oak CA	710	550
San Jose CA	710	510
Seattle-Everett WA	590	400
Northeastern Avg	-	-
Midwestern Avg	210	130
Southern Avg	290	240
Southwestern Avg	300	240
Western Avg	530	380
Texas Avg	340	280
Total Avg	350	260
Maximum Value	960	660
Minimum Value	40	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 22. Component and Total Congestion Costs By Urban Area for 1987

Urban Area	Annual Cost Due to Congestion ($Millions) Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	120	200	20	30	360
Boston MA	240	620	30	90	970
Hartford CT	20	40	0	10	80
New York NY	1,390	2,570	200	370	4,540
Philadelphia PA	360	460	50	60	940
Pittsburgh PA	120	190	20	30	360
Washington DC	560	920	90	140	1,710
Midwestern Cities					
Chicago IL	680	780	100	120	1,680
Cincinnati OH	50	50	10	10	110
Cleveland OH	70	50	10	10	140
Columbus OH	60	50	10	10	120
Detroit MI	420	650	60	100	1,230
Indianapolis IN	-	-	-	-	-
Kansas City MO	20	50	0	10	80
Louisville KY	30	30	0	0	80
Milwaukee WI	60	70	10	10	150
Minn-St. Paul MN	150	140	20	20	340
Oklahoma City OK	-	-	-	-	-
St. Louis MO	180	200	20	30	430
Southern Cities					
Atlanta GA	360	390	50	60	860
Charlotte NC	40	40	10	10	90
Ft. Lauderdale FL	90	110	10	20	240
Jacksonville FL	60	80	10	10	170
Memphis TN	20	30	0	0	60
Miami FL	240	290	40	40	600
Nashville TN	50	50	10	10	120
New Orleans LA	80	120	10	20	230
Norfolk VA	70	150	10	20	250
Orlando FL	90	110	10	20	220
Tampa FL	60	70	10	10	140
Southwestern Cities					
Albuquerque NM	-	-	-	-	-
Austin TX	70	80	10	10	170
Corpus Christi TX	0	0	0	0	10
Dallas TX	280	470	40	70	860
Denver CO	160	170	30	30	390
El Paso TX	10	10	0	0	30
Fort Worth TX	110	180	20	30	330
Houston TX	480	640	70	100	1,290
Phoenix AZ	240	210	40	30	520
Salt Lake City UT	20	20	0	0	50
San Antonio TX	90	100	10	20	230
Western Cities					
Honolulu HI	50	90	10	10	170
Los Angeles CA	2,460	2,890	390	460	6,190
Portland OR	70	120	10	20	220
Sacramento CA	90	80	10	10	200
San Bernardino-Riv CA	270	320	40	50	690
San Diego CA	240	160	40	30	460
San Fran-Oak CA	850	1,070	130	170	2,230
San Jose CA	300	360	50	60	760
Seattle-Everett WA	290	380	50	60	770
Northeastern Avg	400	710	60	100	1,280
Midwestern Avg	170	210	30	30	440
Southern Avg	110	130	20	20	270
Southwestern Avg	150	190	20	30	390
Western Avg	510	610	80	100	1,300
Texas Avg	150	210	20	30	420
Total Avg	250	340	40	50	680
Maximum Value	2,460	2,890	390	460	6,190
Minimum Value	0	0	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 23. Estimated Impact of Congestion in 1987

Urban Area	Total Congestion Cost: Per Registered Vehicle (Dollars)	Total Congestion Cost: Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	370	190
Boston MA	640	340
Hartford CT	160	130
New York NY	790	280
Philadelphia PA	350	230
Pittsburgh PA	300	200
Washington DC	1,060	570
Midwestern Cities		
Chicago IL	430	230
Cincinnati OH	130	120
Cleveland OH	100	80
Columbus OH	170	150
Detroit MI	430	320
Indianapolis IN	-	-
Kansas City MO	120	70
Louisville KY	170	100
Milwaukee WI	290	120
Minn-St. Paul MN	210	180
Oklahoma City OK	-	-
St. Louis MO	450	220
Southern Cities		
Atlanta GA	570	490
Charlotte NC	260	230
Ft. Lauderdale FL	250	200
Jacksonville FL	290	250
Memphis TN	100	70
Miami FL	450	340
Nashville TN	250	230
New Orleans LA	280	220
Norfolk VA	320	290
Orlando FL	360	300
Tampa FL	250	220
Southwestern Cities		
Albuquerque NM	-	-
Austin TX	370	360
Corpus Christi TX	50	40
Dallas TX	550	450
Denver CO	300	260
El Paso TX	90	60
Fort Worth TX	330	290
Houston TX	580	460
Phoenix AZ	440	280
Salt Lake City UT	70	60
San Antonio TX	280	220
Western Cities		
Honolulu HI	340	270
Los Angeles CA	810	570
Portland OR	350	210
Sacramento CA	170	200
San Bernardino-Riv CA	970	680
San Diego CA	350	220
San Fran-Oak CA	760	630
San Jose CA	780	560
Seattle-Everett WA	670	480
Northeastern Avg	520	280
Midwestern Avg	250	160
Southern Avg	310	260
Southwestern Avg	310	250
Western Avg	580	430
Texas Avg	320	270
Total Avg	380	270
Maximum Value	1,060	680
Minimum Value	50	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 24. Component and Total Congestion Costs By Urban Area for 1988

Urban Area	Annual Cost Due to Congestion ($Millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	130	220	20	40	400
Boston MA	320	890	50	130	1,380
Hartford CT	30	70	10	10	120
New York NY	1,580	2,880	240	440	5,130
Philadelphia PA	390	490	60	70	1,010
Pittsburgh PA	150	210	20	30	410
Washington DC	600	990	100	160	1,850
Midwestern Cities					
Chicago IL	700	810	110	130	1,760
Cincinnati OH	70	60	10	10	150
Cleveland OH	80	60	10	10	170
Columbus OH	70	50	10	10	140
Detroit MI	440	680	70	110	1,290
Indianapolis IN	20	30	0	0	60
Kansas City MO	30	60	0	10	100
Louisville KY	30	30	0	0	70
Milwaukee WI	70	70	10	10	170
Minn-St. Paul MN	160	150	30	30	360
Oklahoma City OK	30	40	10	10	80
St. Louis MO	160	180	20	30	390
Southern Cities					
Atlanta GA	350	380	50	60	850
Charlotte NC	50	50	10	10	110
Ft. Lauderdale FL	100	120	20	20	250
Jacksonville FL	70	80	10	10	170
Memphis TN	30	30	0	0	70
Miami FL	290	360	50	60	750
Nashville TN	60	70	10	10	160
New Orleans LA	90	130	10	20	260
Norfolk VA	80	160	10	20	270
Orlando FL	90	110	10	20	230
Tampa FL	60	80	10	10	160
Southwestern Cities					
Albuquerque NM	20	30	0	0	60
Austin TX	70	80	10	10	180
Corpus Christi TX	0	0	0	0	10
Dallas TX	300	510	50	80	930
Denver CO	180	190	30	30	430
El Paso TX	10	20	0	0	40
Fort Worth TX	110	190	20	30	350
Houston TX	510	690	80	110	1,390
Phoenix AZ	300	290	50	50	680
Salt Lake City UT	20	20	0	0	50
San Antonio TX	90	100	10	20	230
Western Cities					
Honolulu HI	60	100	10	20	200
Los Angeles CA	2,510	2,940	410	480	6,340
Portland OR	90	140	10	20	260
Sacramento CA	120	100	20	20	260
San Bernardino-Riv CA	320	380	50	60	820
San Diego CA	280	190	50	30	550
San Fran-Oak CA	900	1,140	150	190	2,380
San Jose CA	330	380	50	60	820
Seattle-Everett WA	330	430	50	70	890
Northeastern Avg	460	820	70	130	1,470
Midwestern Avg	150	190	20	30	400
Southern Avg	110	140	20	20	300
Southwestern Avg	150	190	20	30	400
Western Avg	550	650	90	110	1,390
Texas Avg	160	230	30	40	450
Total Avg	260	350	40	60	700
Maximum Value	2,510	2,940	410	480	6,340
Minimum Value	0	0	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 25. Estimated Impact of Congestion in 1988

Urban Area	Total Congestion Cost: Per Registered Vehicle (Dollars)	Total Congestion Cost: Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	390	210
Boston MA	900	480
Hartford CT	230	190
New York NY	880	310
Philadelphia PA	370	240
Pittsburgh PA	340	220
Washington DC	1,130	610
Midwestern Cities		
Chicago IL	440	240
Cincinnati OH	160	150
Cleveland OH	110	90
Columbus OH	190	160
Detroit MI	450	330
Indianapolis IN	110	60
Kansas City MO	150	90
Louisville KY	160	90
Milwaukee WI	320	140
Minn-St. Paul MN	220	190
Oklahoma City OK	180	120
St. Louis MO	410	200
Southern Cities		
Atlanta GA	550	480
Charlotte NC	300	260
Ft. Lauderdale FL	260	210
Jacksonville FL	290	250
Memphis TN	110	80
Miami FL	550	410
Nashville TN	310	290
New Orleans LA	310	240
Norfolk VA	340	300
Orlando FL	360	300
Tampa FL	270	250
Southwestern Cities		
Albuquerque NM	160	120
Austin TX	370	360
Corpus Christi TX	50	40
Dallas TX	580	480
Denver CO	320	280
El Paso TX	100	70
Fort Worth TX	340	300
Houston TX	620	490
Phoenix AZ	580	370
Salt Lake City UT	70	60
San Antonio TX	250	190
Western Cities		
Honolulu HI	400	300
Los Angeles CA	810	570
Portland OR	430	280
Sacramento CA	210	250
San Bernardino-Riv CA	1,130	790
San Diego CA	400	250
San Fran-Oak CA	790	660
San Jose CA	830	600
Seattle-Everett WA	760	550
Northeastern Avg	610	320
Midwestern Avg	240	160
Southern Avg	330	280
Southwestern Avg	310	250
Western Avg	640	470
Texas Avg	330	280
Total Avg	400	280
Maximum Value	1,130	790
Minimum Value	50	40

Source: TTI Analysis and Local Transportation Agency References

Table 26. Component and Total Congestion Costs By Urban Area for 1989

Urban Area	Annual Cost Due to Congestion ($Millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	150	260	30	40	470
Boston MA	320	880	50	140	1,390
Hartford CT	40	80	10	10	140
New York NY	1,810	3,380	300	560	6,040
Philadelphia PA	400	520	60	80	1,060
Pittsburgh PA	160	230	20	30	440
Washington DC	690	1,140	110	190	2,130
Midwestern Cities					
Chicago IL	780	900	130	150	1,970
Cincinnati OH	70	60	10	10	160
Cleveland OH	90	70	20	10	190
Columbus OH	70	60	10	10	150
Detroit MI	480	740	80	120	1,410
Indianapolis IN	20	30	0	10	60
Kansas City MO	30	60	0	10	100
Louisville KY	30	40	10	10	80
Milwaukee WI	70	80	10	10	180
Minn-St. Paul MN	170	160	30	30	390
Oklahoma City OK	30	40	10	10	80
St. Louis MO	220	250	30	40	540
Southern Cities					
Atlanta GA	370	410	60	70	910
Charlotte NC	50	50	10	10	120
Ft. Lauderdale FL	100	130	20	20	270
Jacksonville FL	80	100	10	20	210
Memphis TN	30	30	10	10	80
Miami FL	330	410	50	70	870
Nashville TN	70	70	10	10	160
New Orleans LA	90	140	20	20	270
Norfolk VA	80	170	10	30	290
Orlando FL	100	130	20	20	270
Tampa FL	70	80	10	10	170
Southwestern Cities					
Albuquerque NM	30	40	10	10	80
Austin TX	80	80	10	10	180
Corpus Christi TX	0	0	0	0	10
Dallas TX	310	530	50	90	980
Denver CO	200	210	30	30	480
El Paso TX	20	20	0	0	40
Fort Worth TX	120	200	20	30	370
Houston TX	550	740	90	120	1,500
Phoenix AZ	320	290	50	50	700
Salt Lake City UT	30	20	0	0	60
San Antonio TX	100	110	20	20	240
Western Cities					
Honolulu HI	70	110	10	20	220
Los Angeles CA	2,750	3,220	480	560	7,000
Portland OR	100	160	20	30	310
Sacramento CA	140	120	30	20	310
San Bernardino-Riv CA	360	420	60	70	920
San Diego CA	320	210	60	40	620
San Fran-Oak CA	980	1,240	170	220	2,620
San Jose CA	360	420	60	70	910
Seattle-Everett WA	380	500	60	80	1,020
Northeastern Avg	510	930	80	150	1,670
Midwestern Avg	170	210	30	30	440
Southern Avg	130	160	20	30	330
Southwestern Avg	160	200	30	30	420
Western Avg	610	710	110	120	1,550
Texas Avg	170	240	30	40	470
Total Avg	280	390	50	60	780
Maximum Value	2,750	3,380	480	560	7,000
Minimum Value	0	0	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 27. Estimated Impact of Congestion in 1989

Urban Area	Total Congestion Cost Per Registered Vehicle (Dollars)	Total Congestion Cost Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	460	250
Boston MA	840	470
Hartford CT	270	230
New York NY	1,020	370
Philadelphia PA	380	250
Pittsburgh PA	360	240
Washington DC	1,280	690
Midwestern Cities		
Chicago IL	480	270
Cincinnati OH	170	140
Cleveland OH	130	110
Columbus OH	200	180
Detroit MI	490	360
Indianapolis IN	110	70
Kansas City MO	150	90
Louisville KY	170	100
Milwaukee WI	330	140
Minn-St. Paul MN	240	200
Oklahoma City OK	180	120
St. Louis MO	570	280
Southern Cities		
Atlanta GA	590	490
Charlotte NC	330	280
Ft. Lauderdale FL	260	210
Jacksonville FL	360	300
Memphis TN	120	90
Miami FL	610	470
Nashville TN	320	290
New Orleans LA	320	260
Norfolk VA	360	310
Orlando FL	380	340
Tampa FL	270	250
Southwestern Cities		
Albuquerque NM	190	160
Austin TX	370	370
Corpus Christi TX	50	40
Dallas TX	660	500
Denver CO	350	310
El Paso TX	110	70
Fort Worth TX	380	320
Houston TX	690	520
Phoenix AZ	590	370
Salt Lake City UT	90	80
San Antonio TX	270	200
Western Cities		
Honolulu HI	440	330
Los Angeles CA	900	620
Portland OR	460	300
Sacramento CA	250	300
San Bernardino-Riv CA	1,200	840
San Diego CA	440	280
San Fran-Oak CA	850	720
San Jose CA	900	650
Seattle-Everett WA	810	610
Northeastern Avg	660	360
Midwestern Avg	270	170
Southern Avg	360	300
Southwestern Avg	340	270
Western Avg	690	520
Texas Avg	360	290
Total Avg	440	310
Maximum Value	1,280	840
Minimum Value	50	40

Source: TTI Analysis and Local Transportation Agency References

CONGESTION TRENDS FOR URBAN AREA GROUPS

Previous sections have presented travel, roadway supply, and congestion statistics for individual urban areas and geographic regions across the United States. Other groupings based on population size and population density were used to further examine the various congestion trends that occur between the urban areas and over the past decade. Grouping areas by population size or population density can reveal how the size of a city, or its development characteristics, are related to congestion. This section presents and examines the various congestion trends for the 50 urban areas grouped by population size and population density.

Population Size

The amount of congestion in an urban area is intuitively related to its population. Larger urban centers tend to be more congested and typically have a range of solutions to address transportation problems, indicating a recognition of the problems of relying on roadway solutions. This section presents an analysis of the relationship between population and congestion level.

For the purposes of this analysis, Chicago, New York, and Los Angeles were separated because of their comparatively large populations, and the remaining areas were divided into four approximately even groups based on the 1990 population estimates (Table 28). Chicago, New York, and Los Angeles have populations much greater than the areas in the adjacent group, and the statistics for these three areas would have distorted the true average statistics for the fourth group. The major Texas urban areas are located in three of the groups: Corpus Christi, Austin, and El Paso are in the first group; San Antonio and Forth Worth are in the third group; and, Dallas and Houston fall into the fourth group. Table 28 also shows the 1990 RCI value and percent change in the RCI from 1982 to 1990 for each urban area in the five groups.

Table 28. Urban Area Grouping by Population Size

Urban Area	Population (1000)	Roadway[1] Congestion Index	Percent Change in Roadway Congestion Index, 1982 to 1990
First Group			
Corpus Christi TX	280	0.72	7
Charlotte NC	450	0.78	16
Austin TX	510	0.94	22
Albuquerque NM	525	0.93	19
El Paso TX	540	0.74	17
Nashville TN	565	0.89	20
Hartford CT	610	0.89	17
Honolulu HI	660	1.11	19
Tampa FL	700	1.05	12
Jacksonville FL	720	0.94	8
Oklahoma City OK	735	0.79	10
Salt Lake City UT	800	0.85	35
Second Group			
Louisville KY	810	0.86	2
Orlando FL	850	0.72	9
Columbus OH	850	0.83	22
Memphis TN	860	0.91	6
Norfolk VA	925	0.96	22
Indianapolis IN	945	0.83	17
Portland OR	1,030	1.07	23
New Orleans LA	1,080	1.12	14
Sacramento CA	1,095	1.02	27
Cincinnati OH	1,140	0.96	12
Kansas City MO	1,160	0.74	19
San Bernardino-Riv CA	1,170	1.19	9
Third Group			
San Antonio TX	1,170	0.88	14
Fort Worth TX	1,200	0.90	18
Milwaukee WI	1,230	0.99	19
Ft. Lauderdale FL	1,270	0.94	9
San Jose CA	1,410	1.04	22
Denver CO	1,580	1.03	21
Seattle-Everett WA	1,730	1.20	26
Cleveland OH	1,790	0.97	21
Miami FL	1,850	1.26	20
Pittsburgh PA	1,865	0.82	5
Atlanta GA	1,875	1.11	25
Phoenix AZ	1,895	1.03	-10
Fourth Group			
St. Louis MO	1,960	0.99	19
Baltimore MD	1,990	1.01	20
Dallas TX	1,990	1.05	25
Minn-St. Paul MN	2,010	0.93	26
San Diego CA	2,295	1.22	56
Houston TX	2,880	1.12	-4
Boston MA	2,955	1.06	18
Washington DC	3,100	1.37	28
San Fran-Oak CA	3,675	1.35	34
Detroit MI	4,000	1.09	-4
Philadelphia PA	4,220	1.05	5
Fifth Group			
Chicago IL	7,510	1.25	23
Los Angeles CA	11,420	1.55	27
New York NY	16,780	1.14	13

Note: [1] See Equation 1

Source: TTI Analysis and Local Transportation Agency References

Mileage and Travel Volume Statistics

The average freeway and principal arterial street mileage and travel volumes (DVMT) for the five population groups are shown in Tables 29 and 30. The general trend is increasing average roadway mileage and travel volumes for an increasing population size. Chicago, New York, and Los Angeles (fifth group) have disproportionately higher travel volumes and roadway mileage than the first four groups. The average DVMT per lane-mile, a measure of the severity of congestion, shows that freeway and principal arterial street congestion is more extensive in the larger population groups.

The magnitude of the freeway DVMT per lane-mile values also indicate that, on the average, urban areas in the fourth and fifth groups experience undesirable areawide levels of congestion on the freeway system. The magnitude of the principal arterial street DVMT per lane-mile values suggest that, on the average, all population groups experience undesirable levels of congestion on principal arterial streets.

Table 29. 1990 Freeway Mileage and Travel Volume Grouped by Population

Population Group	DVMT[1] (1000)	Lane-Miles	Avg. No. Lanes	DVMT/ Ln-Mile[2,3]
Fifth Group	77,100	4,520	6.5	16,950
Fourth Group	23,890	1,680	5.8	14,060
Third Group	12,020	940	5.5	12,570
Second Group	8,210	700	5.5	11,850
First Group	4,350	410	5.1	10,630

Note: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of freeway
[3] Value in excess of 13,000 indicates undesirable level of congestion on area freeway system

Source: TTI Analysis and Local Transportation Agency References

Table 30. 1990 Principal Arterial Street Mileage and Travel Volume Grouped by Population

Population Group	DVMT[1] (1000)	Lane-Miles	Avg. No. Lanes	DVMT/ Ln-Mile[2,3]
Fifth Group	53,820	8,040	3.7	6,780
Fourth Group	13,390	2,220	3.7	5,940
Third Group	8,900	1,550	3.8	5,570
Second Group	4,660	950	3.7	5,160
First Group	3,350	630	3.7	5,530

Note: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of principal arterial street
[3] Value in excess of 5,000 indicates undesirable level of congestion on area principal arterial street system

Source: TTI Analysis and Local Transportation Agency References

1990 Roadway Congestion Index Estimates

The components of the Roadway Congestion Index (RCI) equation and the average 1990 RCI values for the five population groups are shown in Table 31. The average RCI values exhibit the general trend of increasing average levels of congestion for increasing urban area population size. The urban areas with large populations (fourth and fifth group) have undesirable levels of congestion (RCI values of 1.11 and 1.31, respectively), while the average for the medium-size areas (third group) is just beginning to indicate areawide congestion (RCI value of 1.01). Smaller urban areas in the first and second groups have average RCI values of 0.89 and 0.93, below what might be considered areawide congestion.

Table 31. 1990 Roadway Congestion Index Values Grouped by Population

Population Group	Freeway / Expressway		Principal Arterial Street		Roadway[3] Congestion Index
	DVMT[1] (1000)	DVMT/[2] Ln-Mile	DVMT[1] (1000)	DVMT/[2] Ln-Mile	
Fifth Group	77,100	16,950	53,820	6,780	1.31
Fourth Group	23,890	14,060	13,390	5,940	1.11
Third Group	12,020	12,570	8,900	5,570	1.01
Second Group	8,210	11,850	4,660	5,160	0.93
First Group	4,350	10,630	3,350	5,530	0.89

Notes: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile
[3] See Equation 1

Source: TTI Analysis

Roadway Congestion Trends, 1982 to 1990

The average growth in congestion between 1982 and 1990 for the five population groups ranges between 15 and 21 percent (Table 32, Figure 5). Congestion has increased faster in the larger population groups than in the smaller population groups. Interestingly, the average growth in congestion for the smallest study areas in the first group has slightly outpaced growth in the medium to large study areas in the second and third groups.

Table 32. Roadway Congestion Index Values Grouped by Population, 1982 to 1990

Population Group	Year									Percent Change, 1982 to 1990
	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Fifth Group	1.08	1.10	1.12	1.15	1.21	1.23	1.27	1.29	1.31	21
Fourth Group	0.94	0.97	1.00	1.01	1.06	1.08	1.09	1.10	1.11	19
Third Group	0.88	0.90	0.91	0.94	0.96	0.98	0.98	1.00	1.01	15
Second Group	0.81	0.81	0.82	0.84	0.87	0.90	0.92	0.93	0.93	15
First Group	0.76	0.79	0.83	0.83	0.84	0.86	0.87	0.87	0.89	17

Source: TTI Analysis

Travel Delays

Table 33 illustrates travel delay information for the five population groups. Inspection of the table reveals that the average total delay for Chicago, New York, and Los Angeles (fifth group) exceeds 1.2 million vehicle-hours of delay. This means the total delay is over four times that of the other large urban areas in the fourth group. The general trend for the other groups is one of higher delay for larger population size. The total delay per 1000 persons for the five population groups ranges from 110 to 50 vehicle-hours, with lower delay values in smaller population areas.

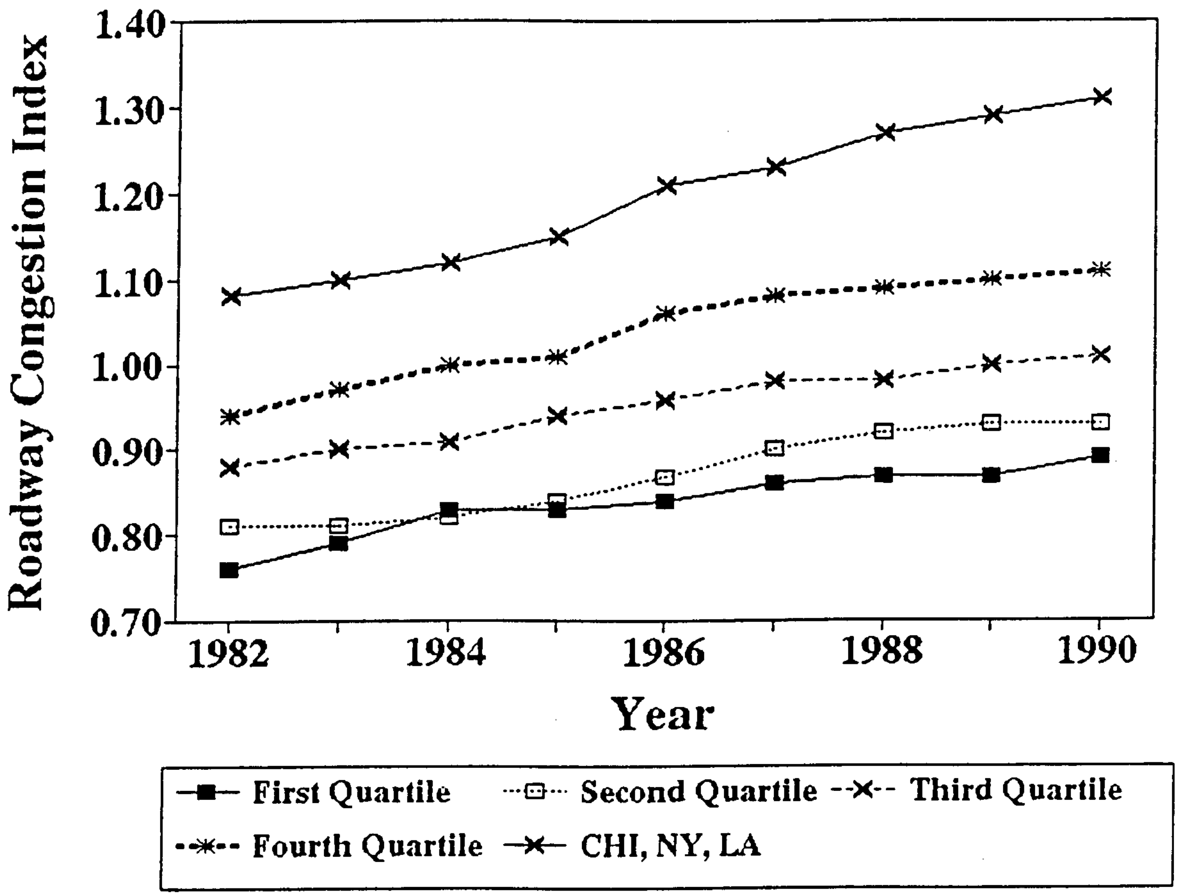

Figure 5. Roadway Congestion Index Values Grouped by Population, 1982 to 1990

Table 33. Total Vehicle Hours of Delay for 1990 Grouped by Population

Population Group	Total Delay (vehicle hours)	Total Delay per 1000 Persons
Fifth Group	1,272,570	110
Fourth Group	302,520	100
Third Group	141,830	90
Second Group	65,050	60
First Group	31,510	50

Source: TTI Analysis

Costs of Congestion

The congestion cost data presented in Table 16 was summarized to determine the average costs of congestion for the five population groups (Table 34). The larger urban areas in the fourth group had average annual congestion costs exceeding $1.3 billion, while the average congestion cost in the fifth group was more than $5.5 billion. The congestion cost per registered vehicle and per capita are also shown in Table 34. These normalized costs, which could also be called a "congestion tax," are the additional loss of money that congestion imposes upon residents of the urban area. The cost per registered vehicle ranged from $880 to $270 for the five population groups, and the annual cost per capita ranged from $460 to $230 per person. The costs per capita in the fourth and fifth group are much lower than the cost per vehicle, which reflects the lower vehicle ownership rate in urban areas in the Northeast and Midwest that comprise most of the cities in those two groups.

Table 34. 1990 Component and Total Congestion Costs Grouped by Population

Population Group	Annual Cost Due to Congestion ($Millions)			Cost per Registered Vehicle ($)	Cost per Capita ($)
	Delay	Fuel	Total		
Fifth Group	4,680	820	5,510	880	460
Fourth Group	1,110	190	1,300	680	450
Third Group	520	90	610	510	380
Second Group	240	40	280	360	270
First Group	110	20	140	270	230

Source: TTI Analysis and Local Transportation Agency References

Population Density

The population density of an urban area provides some indication of the compactness ‹ development. In the United States, a general trend is that older cities in the Northeast a Midwest exhibit more dense development than those cities in the Southern and Southwesten regions. The 50 urban areas in this study were divided into 4 approximately even groups based on the population density (Table 35). Examination of the table reveals that those urban areas with the greatest population density (fourth group) are primarily located in the Northeast or in California. All of the major Texas urban areas are within the first group of population density (1130 to 1755 persons per square mile) with the exception of San Antonio, which falls into the third group. With respect to population density, the urban areas of Chicago, New York, and Los Angeles are comparable to those urban areas in the fourth group and were so included.

Mileage and Travel Volume Statistics

Tables 36 and 37 present the average freeway and principal arterial street mileage and DVMT for the four population density groups. The first three groups have relatively comparable travel and roadway characteristics, while the fourth group has much greater travel volumes and roadway supply for both freeways and principal arterial streets. The average freeway DVMT per lane-mile for the fourth group is greater than 15,000, but the average for the other three is below what could be considered areawide congestion. The average principal arterial street congestion for urban areas in the first, third, and fourth groups could be considered above undesirable levels.

Table 35. Urban Area Grouping by Population Density

Urban Area	Population Density (persons/sq. mi.)	Roadway[1] Congestion Index	Percent Change in Roadway Congestion Index, 1982 to 1990
First Group			
Nashville TN	1130	0.89	20
Norfolk VA	1135	0.96	22
Atlanta GA	1215	1.11	25
Jacksonville FL	1335	0.94	8
Dallas TX	1380	1.05	25
Fort Worth TX	1410	0.90	18
Austin TX	1455	0.94	22
Oklahoma City OK	1470	0.79	10
Tampa FL	1575	1.05	12
Corpus Christi TX	1600	0.72	7
Hartford CT	1695	0.89	17
Salt Lake City UT	1700	0.85	35
Houston TX	1755	1.12	-4
Second Group			
Denver CO	1775	1.03	21
Charlotte NC	1875	0.78	16
Kansas City MO	1900	0.74	19
Phoenix AZ	1945	1.03	-10
Minn-St. Paul MN	1970	0.93	26
Cincinnati OH	2000	0.96	12
Memphis TN	2025	0.91	6
Albuquerque NM	2060	0.93	19
Orlando FL	2075	0.72	9
Louisville KY	2130	0.86	2
Indianapolis IN	2150	0.83	17
Milwaukee WI	2235	0.99	19
Seattle-Everett WA	2385	1.20	26
Third Group			
San Bernardino-Riv	2390	1.19	9
San Antonio TX	2410	0.88	14
Portland OR	2450	1.07	23
Pittsburgh PA	2520	0.82	5
El Paso TX	2570	0.74	17
St. Louis MO	2685	0.99	19
Columbus OH	2740	0.83	22
Boston MA	2760	1.06	18
Cleveland OH	2775	0.97	21
Ft. Lauderdale FL	2955	0.94	9
New Orleans LA	3000	1.12	14
Sacramento CA	3040	1.02	27
Fourth Group			
San Jose CA	3135	1.04	22
Detroit MI	3185	1.09	-4
San Diego CA	3230	1.22	56
Baltimore MD	3620	1.01	20
Washington DC	3690	1.37	28
Philadelphia PA	3735	1.05	5
Chicago IL	3775	1.25	23
Miami FL	3855	1.26	20
San Fran-Oak CA	4350	1.35	34
Honolulu HI	4890	1.11	19
Los Angeles CA	5225	1.55	27
New York NY	5270	1.14	13

Note: [1] See Equation 1

Source: TTI Analysis and Local Transportation Agency References

Table 36. 1990 Freeway Mileage and Travel Volume Grouped by Population Density

Pop. Density Group	DVMT[1] (1000)	Lane-Miles	Avg. No. Lanes	DVMT/ Ln-Mile[2,3]
Fourth Group	34,390	2,150	6.0	15,060
Third Group	10,580	870	5.6	12,090
Second Group	8,960	760	5.1	11,430
First Group	10,230	810	5.4	11,670

Note: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of freeway
[3] Value in excess of 13,000 indicates undesirable level of congestion on area freeway system

Source: TTI Analysis and Local Transportation Agency References

Table 37. 1990 Principal Arterial Street Mileage and Travel Volume Grouped by Population Density

Pop. Density Group	DVMT[1] (1000)	Lane-Miles	Avg. No. Lanes	DVMT/ Ln-Mile[2,3]
Fourth Group	23,550	3,550	3.9	6,640
Third Group	7,050	1,300	3.6	5,500
Second Group	6,030	1,210	3.6	4,980
First Group	5,080	940	3.8	5,420

Note: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of principal arterial street
[3] Value in excess of 5,000 indicates undesirable level of congestion on area principal arterial street system

Source: TTI Analysis and Local Transportation Agency References

1990 Roadway Congestion Index Estimates

The average congestion levels (as represented by the RCI values) for the four population density groups are shown in Table 38. Urban areas in the fourth group have an average level of congestion 20 percent greater than what might be considered the beginning of areawide congestion (RCI value of 1.20). The other three groups have average congestion levels slightly less than the threshold for average areawide congestion.

Table 38. 1990 Roadway Congestion Index Values Grouped by Population Density

Pop. Density Group	Freeway / Expressway		Principal Arterial Street		Roadway[3] Congestion Index
	DVMT[1] (1000)	DVMT/[2] Ln-Mile	DVMT[1] (1000)	DVMT/[2] Ln-Mile	
Fourth Group	34,390	15,060	23,550	6,640	1.20
Third Group	10,580	12,090	7,050	5,500	0.97
Second Group	8,960	11,430	6,030	4,980	0.92
First Group	10,230	11,670	5,080	5,420	0.94

Notes: [1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile
[3] See Equation 1

Source: TTI Analysis

Roadway Congestion Trends, 1982 to 1990

The average congestion levels from 1982 through 1990 for the four population density groups are presented in Table 39. The urban areas with the highest population density (fourth group) have exhibited the largest increase in congestion at 21 percent. The other three groups have experienced a slower growth in congestion, increasing between 13 and 16 percent between 1982 and 1990. Figure 6 provides a graphical picture of congestion trends for the four groups over the past 8 years.

Table 39. Roadway Congestion Index Values Grouped by Population Density, 1982 to 1990

Pop. Density Group	Year									Percent Change, 1982 to 1990
	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Fourth Group	0.99	1.01	1.04	1.05	1.11	1.13	1.16	1.19	1.20	21
Third Group	0.83	0.85	0.86	0.89	0.92	0.93	0.96	0.96	0.97	16
Second Group	0.81	0.82	0.83	0.85	0.87	0.89	0.89	0.91	0.92	13
First Group	0.81	0.84	0.88	0.89	0.91	0.92	0.93	0.93	0.94	16

Source: TTI Analysis

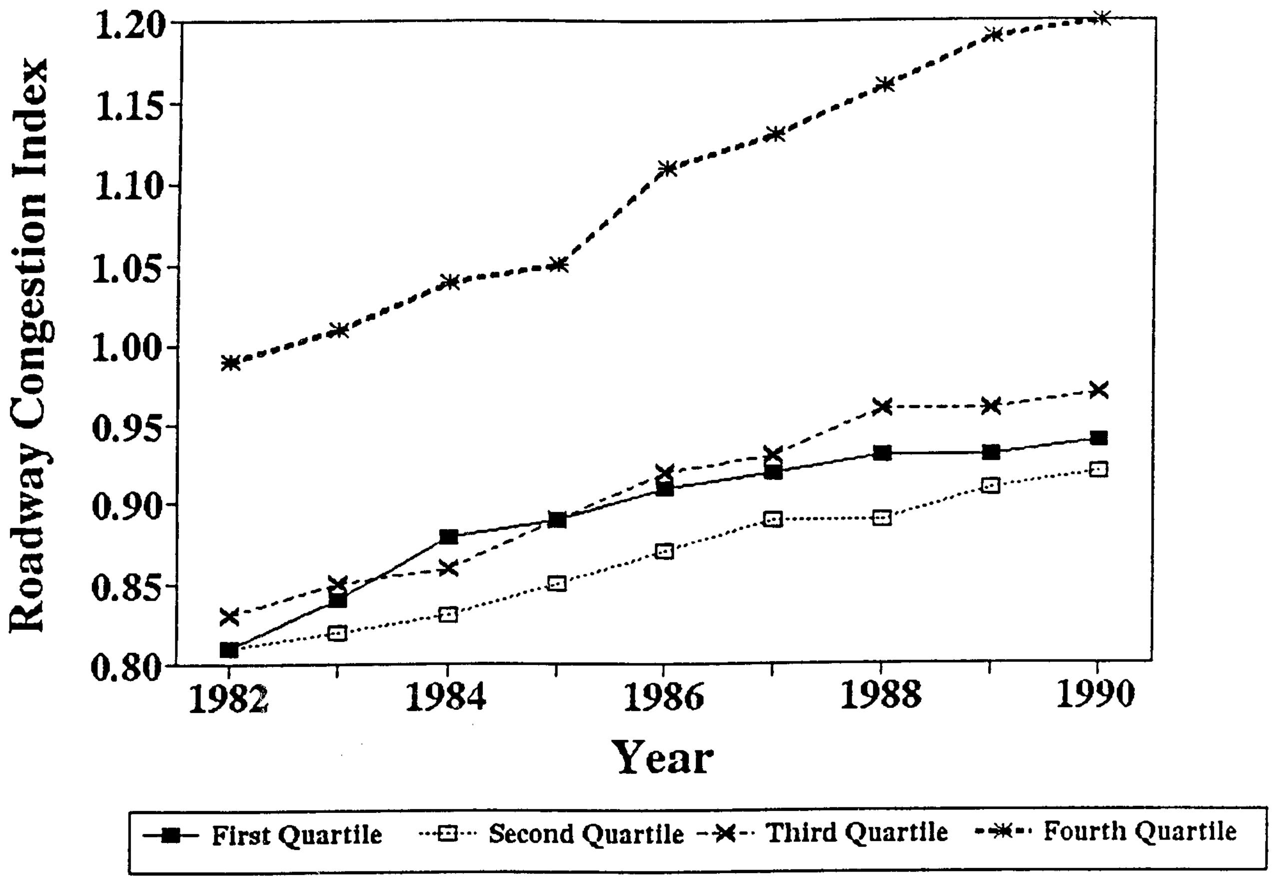

Figure 6. Roadway Congestion Index Values Grouped by Population Density, 1982 to 1990

Travel Delays

Table 40 presents the average delay for the four groups. Again, urban areas in the fourth group of population density experience greater than four times the average amount of total delay as areas in any of the other groups. The total delay per 1000 persons ranges from 110 vehicle-hours for the fourth group to 60 vehicle hours for the second group.

Table 40. Total Vehicle-Hours of Delay for 1990 Grouped by Population Density

Pop. Density Group	Total Delay (vehicle-hours)	Total Delay per 1000 Persons
Fourth Group	536,530	110
Third Group	106,860	70
Second Group	75,230	60
First Group	100,580	70

Source: TTI Analysis

Costs of Congestion

The annual congestion costs for delay and wasted fuel are shown in Table 41. The average total delay and fuel cost for urban areas in the fourth group is $2.32 billion per year, over five times the cost incurred by congestion in any of the other groups. The congestion costs per vehicle range from $750 for the fourth group to $340 for the second group. The cost per capita is slightly lower, ranging from $470 in the fourth group to $250 in the second group. As illustrated earlier, the larger difference in costs per capita and per vehicle in the cities in the fourth group reflects the lower vehicle ownership rates of urban areas with high population density.

Table 41. 1990 Component and Total Congestion Costs Grouped by Population Density

Pop. Density Group	Annual Cost Due to Congestion ($Millions)			Cost per Registered Vehicle ($)	Cost per Capita ($)
	Delay	Fuel	Total		
Fourth Group	1,970	340	2,310	750	470
Third Group	390	70	460	450	310
Second Group	270	40	310	340	250
First Group	380	70	450	430	320

Source: TTI Analysis and Local Transportation Agency References

CONCLUSIONS

This research report represents the results of the fifth year analysis of a six-year research effort focused on quantifying urban mobility. Relative mobility levels in 50 urban areas throughout the country were presented and discussed in this report. The 50 urban areas studied include the seven largest in Texas and a representative cross section of other large urban areas.

The Roadway Congestion Index (RCI) is one measure of urban mobility levels. This value is based on daily vehicle-miles of travel per lane-mile of roadway. The RCI values are intended to be areawide rather than site specific representations of congestion level.

The RCI values in Table 6 illustrate the growing congestion problem in medium and large urban areas in the United States. Congestion exceeded desirable levels in 24 areas in 1990, up from 11 in 1982. Only three of the 50 areas, Phoenix, Houston and Detroit, have had decreases in congestion between 1982 and 1990.

In 1982, eleven urban areas had achieved levels of undesirable congestion, by 1986, seven additional areas had reached or surpassed the point at which undesirable levels of congestion occur. This same trend of growth in congestion, continued through 1990 with six additional urban areas reaching a level of undesirable congestion bringing the total number of cities with undesirable levels of congestion to 24.

Ten more urban areas have estimated RCI values ranging between 0.97 and 0.90. These areas may not experience undesirable levels of congestion in the immediate future; however, congestion levels could become undesirable within the next five to ten years.

Houston (tied for 10th) was the only Texas urban area which was included in the ten most congested urban areas. Dallas (tied for 17th) was the second highest ranked area within the state. Austin was the third highest ranked (tied at 30th) urbanized area in the state with the remaining four Texas cities not ranked in the top 30.

The cost of congestion in the 50 urban areas studied exceeded $43.2 billion in 1990. Thirteen areas had costs greater than or equal to $1 billion. These 13 areas accounted for $31.2 billion or about 74 percent of the congestion costs of the 50 urban areas studied. It can be seen in Table 16 that delay, both recurring and incident, accounted for approximately 85 percent of the congestion costs of an urban area, while excess fuel consumption accounts for the remainder. Increases in delay and fuel costs averaged about 11 percent annually between 1987 and 1990. Twenty-seven of the 50 areas had annual increases greater than or equal to 10 percent.

The effects of congestion costs on the individual can be seen by relating cost to population and vehicle ownership. Washington, D.C. has the highest cost per registered vehicle at $1,420, while San Bernardino-Riverside has the highest cost per capita at $880. The average cost per vehicle and cost per capita are $480 and $340, respectively. The average annual growth of both these values was 9 percent between 1987 and 1990 (in unadjusted dollars). Twenty-four areas had cost per vehicle growth rates equal to or greater than 10 percent over the four year period. Twenty-three areas had cost per capita annual growth rates equal to or greater than 10 percent between 1987 and 1990.

There are many different ways to group the urban areas in order to view trend characteristics. One such way is by population. When grouping the study areas by population, it is possible to see the quantity of congestion present in certain general sizes of urban area. Table 31 shows the DVMT, DVMT per lane mile, and RCI value for five population groups. The smallest urban areas, group one, have an average RCI value of 0.89. This shows that these smaller areas, populations less than or equal to 800,000, are approaching the level where areawide congestion is occurring. Group 3, comprised of urban areas whose population is between 1.17 and 1.90 million, has an average RCI value of 1.01. This shows that, on the average, congestion is already occurring in areas of this size.

Differences in the rankings within Table 18 indicate that no single measure of congestion can capture all of the aspects of the congestion issue. Table 8 similarly indicates that the amount of roadway capacity necessary to achieve a constant congestion level is beyond the ability of most medium and large urban areas. While much discussion centers on reducing congestion, it would seem that on an areawide basis, a more realistic goal for the roadway system would be to maintain existing congestion levels.

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